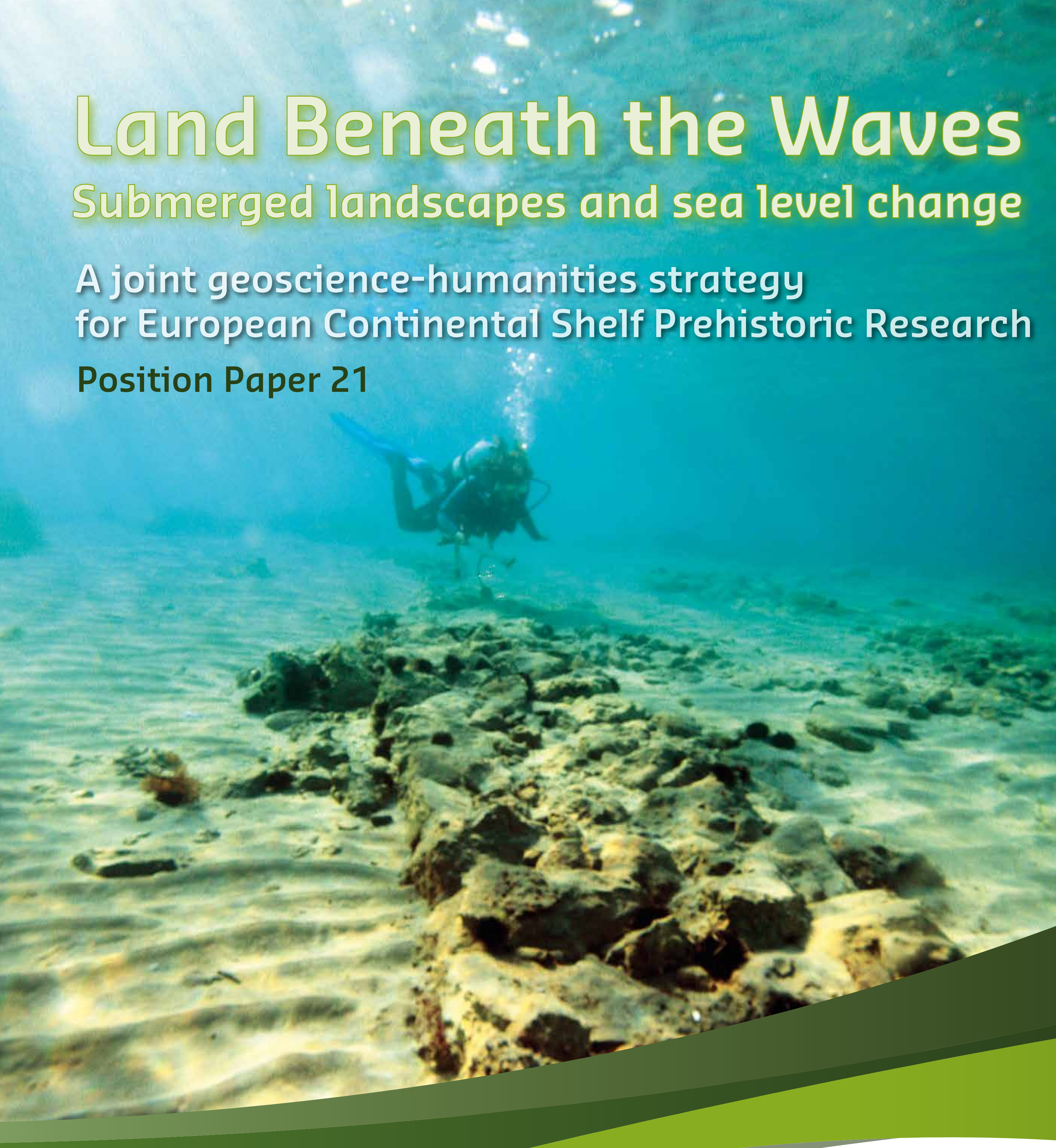
Land Beneath the Waves

Submerged landscapes and sea level change

A joint geoscience-humanities strategy for European Continental Shelf Prehistoric Research

Position Paper 21



European MARINE BOARD
Advancing Seas & Oceans Science

www.marineboard.eu

European Marine Board

The Marine Board provides a pan-European platform for its member organizations to develop common priorities, to advance marine research, and to bridge the gap between science and policy in order to meet future marine science challenges and opportunities.

The Marine Board was established in 1995 to facilitate enhanced cooperation between European marine science organizations towards the development of a common vision on the research priorities and strategies for marine science in Europe. Members are either major national marine or oceanographic institutes, research funding agencies, or national consortia of universities with a strong marine research focus. In 2014, the Marine Board represents 35 Member Organizations from 18 countries.

The Board provides the essential components for transferring knowledge for leadership in marine research in Europe. Adopting a strategic role, the Marine Board serves its member organizations by providing a forum within which marine research policy advice to national agencies and to the European Commission is developed, with the objective of promoting the establishment of the European *marine* Research Area.

www.marineboard.eu

European Marine Board Member Organizations

belspo

fnrs LA LIBERTÉ DE CHERCHER

fwo Research Foundation Flanders Opening new horizons

RB

INSTITUT ZA OCEANOGRAFIJU I RIBARSTVO SPLIT

Oceanography Center Cyprus

DTU Aqua National Institute of Aquatic Resources

Academia Scientiarum Estoniae

cnrs

Ifremer

UNIVERSITÉS MARINES

DFG Deutsche Forschungsgemeinschaft

GEOMAR

HELMHOLTZ ASSOCIATION

KDM Konsortium Deutsche Meeresforschung

hcmr ΕΛΚΕΘΕ

Irish Marine Universities Consortium

Marine Institute Foras na Mara

CoNISMa Consorzio Nazionale Interuniversitario per le Scienze del Mare

National Research Council of Italy

OGS

NWO Netherlands Organisation for Scientific Research

NIOZ Royal Netherlands Institute for Sea Research

INSTITUTE OF MARINE RESEARCH HAVFORSKNINGSINSTITUTTET

The Research Council of Norway

Universitas Bergensis

PAN

CIMAR LABORATÓRIO ASSOCIADO

FCT Fundação para a Ciência e a Tecnologia MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

INCDM

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

INSTITUTO ESPAÑOL DE OCEANOGRAFÍA 1914

TÜBİTAK

MASTS

NERC SCIENCE OF THE ENVIRONMENT

National Oceanography Centre NATURAL ENVIRONMENT RESEARCH COUNCIL

Land Beneath the Waves
Submerged landscapes and sea level change

A joint geoscience-humanities strategy for European Continental Shelf Prehistoric Research

European Marine Board Position Paper 21

This position paper is based on the activities of the European Marine Board Working Group Submerged Landscapes (WG SUBLAND)

Coordinating author & WG Chair

Nicholas C. Flemming

Contributing Authors

Nicholas C. Flemming, M. Namık Çağatay, Francesco Latino Chiocci, Nena Galanidou, Gilles Lericolais, Hauke Jöns, Tine Missiaen, Fionnbarr Moore, Alar Rosentau, Dimitris Sakellariou, Birgitte Skar, Alan Stevenson, and Henk Weerts

Series Editor

Niall McDonough

Publication Editors

Nan-Chin Chu and Niall McDonough

External Reviewer

Peter Veth, Winthrop Professor in Archaeology, The University of Western Australia

Observers and acknowledgement

Geoff Bailey and Deukalion Planning Group (Annex 2)
Anders Fischer, Sunhild Kleingärtner and Ian Oxley

Drafts of this position paper were circulated for comment and information to Members of the European Archaeological Council, Working Group on the Underwater Cultural Heritage one month before its final revision for publication.

Geoff Bailey, Fabrizio Antonioli and Martin Sayer are thanked for their contributions to the position paper.

Suggested reference

Flemming, N.C., Çağatay, M.N., Chiocci, F.L., Galanidou, N., Jöns, H., Lericolais, G., Missiaen, T., Moore, F., Rosentau, A., Sakellariou, D., Skar, B., Stevenson, A., Weerts, H. (2014) Land Beneath the Waves: Submerged landscapes and sea level change. A joint geoscience-humanities strategy for European Continental Shelf Prehistoric Research. Chu, N.C. and McDonough, N. (Eds.) Position Paper 21 of the European Marine Board, Ostend, Belgium. 171 pp. ISBN 978-94-920430-3-0

www.marineboard.eu
info@marineboard.eu

European MARINE BOARD
Advancing Seas & Oceans Science

v.1 October 2014

Foreword

Most people tend to consider the European map as fixed. However, in geological timescales our land-sea boundaries are in a continual state of change. The seabed stretching off many of our European coasts, now covered in tens of metres of water, was once dry land. These areas supported a terrestrial biota including, at a certain point in time, early human populations. The idea that we once lived at the bottom of today's seas is one that easily fires the human imagination. What is more surprising, and until recently poorly recognized, is that there remains an extensive archaeological record of early human settlement on the seabed and sub-seabed of our continental shelf seas. The study of this record and what it tells us about our early human ancestors, their lifestyles and movements over time influenced by a changing environment, is called Continental Shelf Prehistoric Research.

Today the demands for space in our coastal seas are growing at a rapid pace. Human activities such as fishing, aquaculture, shipping, pipe and cable-laying (energy and telecommunications), dredging, offshore wind energy, defence and recreation are all competing for limited space. Many of these activities are also altering the marine environment. For the maritime archaeology community, these activities represent a double-edged sword. On the one hand they can damage and destroy culturally valuable sites and artefacts; on the other, they can alert us to the existence of sites that might otherwise have remained undiscovered. Managing the relationship between the research community and industry is a key issue addressed in this paper.

Since adoption of the Integrated Maritime Policy in 2007, the EU has been working to promote a coherent and integrated approach to managing marine activities and resources in European seas. More recently, the EU Blue Growth Strategy has placed a clear policy priority on the need to expand our maritime economy, providing growth and employment in our coastal regions. In July 2014, the EU adopted a new Directive on Maritime Spatial Planning[1], a key tool for achieving the goals of the IMP. In the text of the Directive, cultural heritage is recognized as one of the key "users of maritime space." Recognition is finally being made that our submerged cultural heritage is not a renewable resource; it is a unique, irreplaceable cultural asset, which can provide answers to many research questions about our prehistoric ancestors, landscapes and climate.

In recent years there has been a major shift in the level of interest and coordination amongst a specialized community of researchers dedicated to Continental Shelf Prehistoric Research. This new integrated research field brings together diverse disciplines across the humanities and geosciences. Considerable momentum has been built through cross-disciplinary networking initiatives, including the now-complete COST action, SPLASHCOS. These initiatives, in conjunction with major advances in marine survey tools and technologies, have been the catalyst for the discovery of many new submerged sites. But there are still a potentially enormous number of sites which remain undiscovered. The European Marine Board (EMB) recognized the importance of addressing this issue and convened an expert working group to consider the next major research priorities and support mechanisms to allow progress in this field.

This paper is the result of the extensive efforts of the SUBLAND working group, the members of which are listed inside the front cover. They have provided a comprehensive analysis of the state of the art in this field, the key opportunities and barriers to progress, and a coherent set of recommendations which can guide research funders and policy makers on how to advance the study and management of our submerged prehistoric cultural heritage.

On behalf of the EMB member organizations, I would like to thank the members of the SUBLAND working group for their enthusiasm and commitment in delivering this excellent position paper. My particular thanks goes to Dr. Nic Flemming, the working group Chair, who has been tireless in his dedication to the SUBLAND initiative and has provided outstanding leadership throughout. Thanks also to Dr. Nan-Chin Chu of the EMB Secretariat for guiding the process with efficiency and professionalism. The paper that they have produced sets an agenda for future research and awareness-raising, and represents an important milestone in the development of Continental Shelf Prehistoric Research.

Jan Mees
Chair, European Marine Board

[1] CDIRECTIVE 2014/89/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 July 2014 establishing a framework for maritime spatial planning. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.257.01.0135.01.ENG

Table of contents

Pavlopetri
Olivia Byard

"the oldest submerged townsite"

Now we know how their world
ended, not just with the seismic shift's
tweaked foreshore, houses tipped
down to the shore-edge,
                    but from
slow encroaching waters.
The sea lapped foundations
and crept into cellars, until
empty and derelict, they were
greedily claimed.

               Here, right now,
a road's shaved by a sheered cliff,
and a house hangs by threads
from the land's burst jaw;
               but there's
wriggle space for us in the displacements
of ancestors, who took with them
just a fat wad of stories,
               and left behind
their best guest pots and chalices,
and tiny house graves
picked clean long ago by molluscs
and other bottom feeders.

Credit: BBC

CGI visualization of a Pavlopetri building after an earthquake.

Olivia Byard is a poet deeply concerned with environmental issues. This poem (first published in the New Statesman in 2012) reveals drowned landscapes as precious marine treasures -- there to warn, teach us, and be a focus for hope.

Website: www.oliviabyard.com

Executive Summary

During the last one million years the land area of Europe was at times 40% larger than at present, and was usually 10-20% larger because of the global volumes of water locked up in ice-caps several kilometres thick on land. Our human precursors lived 200km inland from the coast of the Black Sea more than 1.5 million years ago; in northern Spain more than 1 million years ago, and on the British coast of the North Sea at least 800,000 years ago. Early tribes migrated from Africa through the Middle East, and then along the Mediterranean shore, as well as through central Europe, occupying northern territories when the ice melted and retreating southward when the ice expanded. These migrations across continental shelves, including the abandonment and re-occupation of ancient coastal plains, took place many times.

Continental Shelf Prehistoric Research is a new integrated discipline linking the analysis of climate change, sea-level change, environmental conditions, and the prehistoric archaeology of peoples who lived on and migrated across the continental shelf, land now submerged beneath the sea.

It requires collaboration between experts in the humanities and earth sciences, as well as collaboration with offshore industries such as hydrocarbons, wind farm installations, fishing, dredging, and channel maintenance. Modern technology in seabed acoustic survey, data acquisition, diving technology, data storage and predictive modelling make it possible to envisage a proactive strategy which would have been impossible 10-20 years ago. Costs can be kept to a minimum by combining the initial surveys needed for Continental Shelf Prehistoric Research with those already being conducted for environmental impact assessment and national and regional environmental monitoring requirements. Europe leads the world in this research, and it is imperative to consolidate and expand this advantage.

The variable and partial traces of early humans found on land cannot be fully understood unless we can study and include the large proportion of data on the sea floor. Submerged sites include those that demonstrate the earliest stages of seafaring and exploitation of marine resources. Already more than 2,500 submerged prehistoric sites have been found and catalogued in the European seas mostly dating from 5,000-20,000 years old, with a few in the range of 20,000 to 350,000 years old. Organic materials such as wooden huts, canoes, paddles, rope, string, charcoal, and fish-traps that are found underwater are seldom found in dry-land sites of the same age.

Several refereed books and articles have been published in recent years, and the number is growing exponentially. A vigorous community of researchers in this field has been established and the field has gained significant momentum which needs to be further developed. Public interest in the subject has been generated through TV programmes and frequent articles in the popular press. Additional discoveries on the seabed will provide new potential for museums and regional exhibits in coastal cities and tourist regions.

As a substantial part of the European cultural heritage, seabed prehistory is covered by treaties and international agreements. Promoting this research at the scale of the European sea basins supports the objectives of the European Integrated Maritime Policy and its environmental pillar, the Marine Strategy Framework Directive. Through the development of macro-regional strategies (e.g. for the Baltic, Adriatic and Ionian Seas and Europe's Atlantic margin) the European Union has identified Europe's sea basins and the most appropriate geographical scale for managing Europe's marine territories and resources. In addition, this paper illustrates the importance of industry cooperation in the protection of maritime cultural heritage. Hence, the importance of aligning Continental Shelf Prehistoric Research with the EU's Blue Growth agenda, while perhaps not initially obvious, becomes clear on further analysis. The Integrated Maritime Policy also places the use of common approaches to the implementation of Marine Spatial Planning (MSP) amongst EU Member and Associated States as a high priority. Already several coastal states have included seabed prehistoric site management in their MSP frameworks. By including seabed prehistoric sites, and other submerged archaeological objects such as shipwrecks in MSP, offshore operators are saved the uncertainty that arises from discovery of sites when work has started and management of cultural heritage resources becomes more efficient.

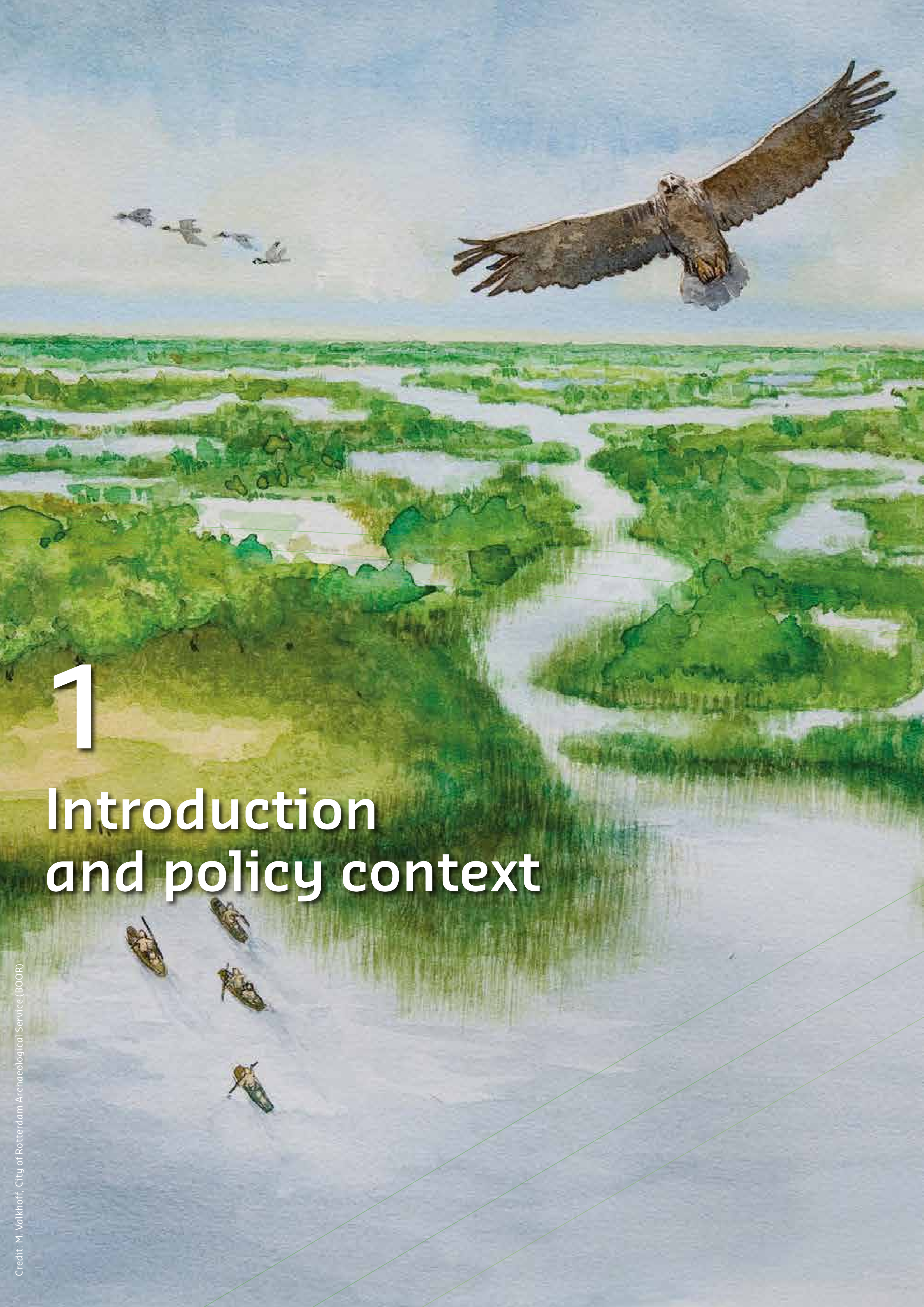
But there are many challenges to achieving effective management and research of submerged prehistoric sites. Problems include the lack of recognition of the subject in archaeological training and university courses; damage to sites through natural erosion and climate change; industrial disturbance, difficulty of integrating or accessing data across disciplinary boundaries, or obtaining data of commercial origin; lack of standards for best practice; few multi-national projects across state boundaries; lack of specialized software for converting seabed acoustic data to reconstructions of terrestrial landscapes; the difficulty of creating a systematic understanding of the geoarchaeological processes that determine site survival; the great range of different seabed environments in the different regional seas of Europe, ranging from rocky cliff or sediment-rich coasts, through enclosed sea basins, and low-sediment rocky coasts in almost tideless clear waters. Critically, the protection of seabed prehistoric sites as cultural heritage is recognized by most coastal states, but the procedures for identification, assessment, survey, abandonment, protection, or excavation are still experimental and not fully developed. With respect to education and training, a few universities do provide courses in which the subject is included, but seldom at an intensive level.

Despite significant recent advances in marine survey and observation technologies, the demands of the new discipline for very high resolution acoustic data over wide areas create unusual requirements even by commercial standards. By working with industry, integrating data management with existing European projects, and improving accessibility to data, these problems can be significantly reduced. New technologies are specifically needed to confirm site existence within areas of high potential, possibly involving geochemical or other innovative techniques. A questionnaire survey of European national heritage agencies conducted by the working group in the process of producing this paper has established a list of archaeological objectives which are rated as the most important.

Maintaining the momentum that has already been developed in this field will require multi-national collaboration supported by both national and European funding and policy. National agencies and the small number of universities currently involved cannot support the scale of activity that is required, or ensure compliance with existing treaties and legislation. The EU Horizon 2020 programme and the Joint Programming Initiatives are key programmes that are well placed to support the scale of collaborative research necessary to address the research goals outlined in the paper. In addition, the costs of ship time and advanced oceanographic technology can be optimized by collaboration between marine research agencies, industry, and the archaeological institutions.

Continental Shelf Prehistoric Research needs to build on the experience and momentum of the COST Action, SPLASHCOS, to improve communication and collaboration between a growing community of scholars and to offer European experience and services globally. It is clear that despite the major progress that has been made in this broad and interactive research field, there is still much to be done to ensure that Europe's submerged prehistoric cultural heritage is managed in an optimal way taking account of the needs of many stakeholders. The publication of this European Marine Board position paper provides a status report and needs assessment, which should help both research funders, the research community and policy makers to gain a better understanding of the challenges and opportunities we face in the next decade and beyond.

1 Introduction and policy context



Credit: M. Valkhoff, City of Rotterdam Archaeological Service (BOOR)

1.1 Background and rationale

Europe was 40% larger 20,000 years ago- who lived there?

Various reports of lost cities under the sea, marooned Neanderthals signalling for help as the Dogger Bank is inundated, or semi-biblical crossings of the Red Sea have always fascinated the media and the public. Myths of floods and drowned civilizations exist worldwide, across many different cultures, and attract speculation and fabulous exaggeration. The truth is more complex but almost as strange as the myths and legends. The evidence for six or more large glaciations in the last million years, each lasting about 125,000 years, and creating ice caps many kilometres thick on the major northern continents, interspersed with smaller glacial advances and retreats, is now well established. The last one was at its maximum 20,000 years ago when the Fennoscandian shield, the Baltic region and most of the British Isles were permanently covered by ice (Svendsen *et al.,* 2004) (Fig 1.1). For each glacial cycle the formation of enormous ice sheets on land drew water from the sea, and, as a result, the sea level dropped by about 120m (Fig 1.2). As a consequence, during each cycle, and signally at the last glacial maximum (LGM), the continental shelf around Europe was exposed to an extent of 3.2 million km² of new dry land, adding 40% to the area of modern Europe (Fig 1.3). Because the earth's crust was also distorted by the weight of ice, and the mass of ice exerts a gravitational pull on the sea water, the local relative sea changes could also be greater or less than 120 m.

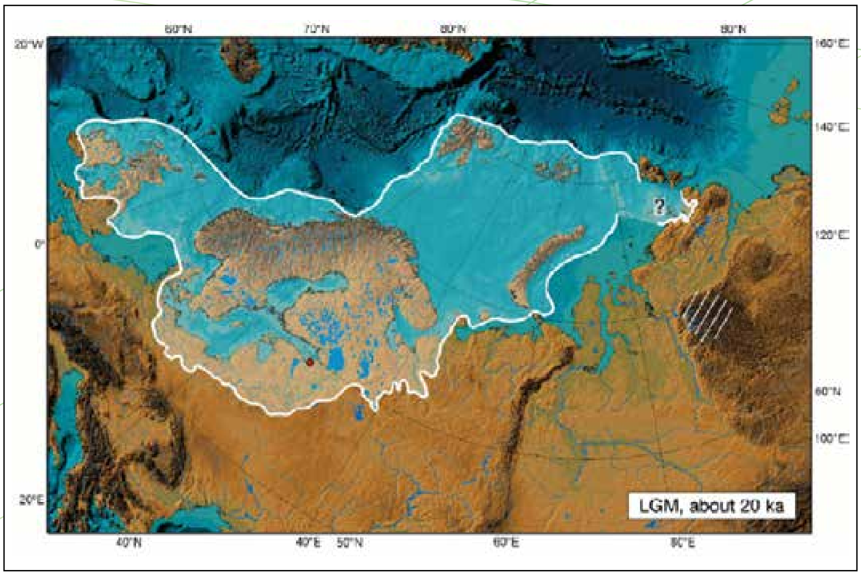


Fig. 1.1 Extent of the ice cap in northern Europe at the last glacial maximum 20,000 years ago. Note centre of ice over Scandinavia and the Baltic where the ice was about 3km thick (from Svendsen *et al.,* 2004). Different models compute that the ice formed two masses that did not quite join at the centre of the North Sea. There were probably multiple ice domes, and their distribution is not yet resolved.

As the sea flowed over the plains of the southern North Sea basin 10,000 years ago, vast areas of wetland and marshes were formed, which provided ideal living space for Mesolithic tribes exploiting fish, shellfish, and 'wild animals'.

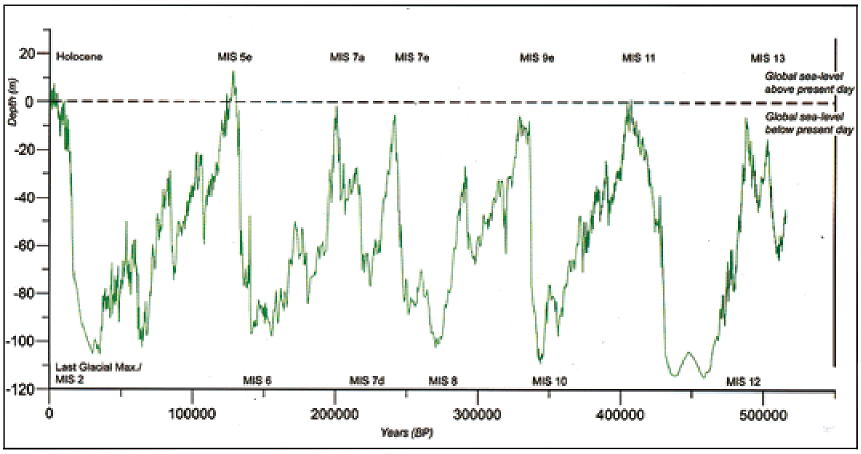


Fig. 1.2 Global sea level during the last 500,000 years oscillated between 120-130m below present sea level and 5-10m above present sea level. Since the sea was lower than at present for most of the last million years, large areas of land were exposed and were occupied by terrestrial vegetation, animals, and early humans (data from Rohling *et al.,* 2009).

Fig. 1.3 After the last glacial maximum, as the ice melted, the land began to rise out of the sea, and the land area of Europe was 40% larger than it is now. This visualization omits the residual ice that would have remained on central Scandinavia and part of Scotland. People hunted and lived over much of this exposed land, and probably exploited peri-glacial fauna such as seals and walrus in the northern parts, adapting to life close to the ice.

Credit: NASA World Wind/Sea Level add-on

Immediately questions arise: Who or what lived on the new land? Was it inhabitable by people or animals? At what dates or periods in the past was the land exposed? How did the enlarged geography of Europe affect migrations into the continent from Africa and the Middle East? How did people respond to falling sea levels, and how did they preserve their basis of subsistence when the land was inundated again? How did they react to continuous climate change? When did humans, or our hominin precursors, first learn to exploit fishing and shellfish, and where and when did they build the first rafts or boats? What unique configurations of fauna, vegetation and people existed during those climatically unique times on the exposed shelves producing the antecedents of the more recent marine provinces, especially from the mid-Holocene?

These questions have intrigued archaeologists for many decades (e.g. Reid, 1913; Louwe Kooijmans, 1972; Fischer, 1995; Yanko-Hombach *et al.*, 2007) and the answers lie beneath the sea in the mud and sediments of the continental shelf. It requires the combined skills of archaeologists, palaeontologists, oceanographers, marine geologists and experts in climate change to decipher the clues on the sea floor. Additionally, a wide range of technical and engineering skills are required to conduct the work at sea and on the seafloor (Fig. 1.4). We call this new composite subject *Continental Shelf Prehistoric Research*.

Credit: J. Henderson

Fig. 1.4 Diving archaeologist using an air-lift suction device to remove sediment cover over large pottery jars buried on the sea floor at the Early Bronze Age submerged town of Pavlopetri, southern Greece.

BOX 1.1 Prehistoric Archaeological Sites on the Sea Floor: Definitions and Facts

- The continental shelf extends the present land area of Europe by 40% and was exposed as dry land to a depth of about 120-135m at extreme Pleistocene glaciations. The sea has been below present sea level for most of the last million years.
- Vegetation remains, pollen, peat, river valleys, terrestrial landforms, shoreline features, cliffs, caves, deltas, and other environmental indicators can and do survive on some parts of the continental shelf.
- Modern high-resolution survey, mapping, sampling and modelling techniques allow us to reconstruct the submerged terrestrial environment at different dates, provided that we have enough observation and data.
- Prehistoric terrestrial faunal and human remains can and do survive on the continental shelf, and thousands of palaeontological and prehistoric archaeological sites have been found in European seas and coastal waters, of which over 2,500 show evidence of human activity.
- These sites help us to reconstruct reliably the patterns of successive migrations into and out of the regions of Europe, and to decipher the origins of seafaring and marine resource exploitation. This analysis is just beginning using the continental shelf data.

When people are told that there are thousands of prehistoric sites on the sea floor, human settlements and places of occupation ranging from 5,000 to more than 100,000 years old, their first reaction is often incredulity or scepticism (Bailey and Flemming, 2008). This reaction is usually the case both for expert archaeologists and the general public alike. How can it be true that fragile unconsolidated deposits of human remains, charcoal, food debris, scattered stone tools, débitage fragments of waste from flint knapping, wooden hut posts, and bits of bone or fragments of wooden canoes survive first the process of post-glacial rising sea levels and transit through the surf zone, and then thousands of years submerged under present oceanic and coastal conditions? How and why do they survive, and how can we discover their most probable locations? Can we predict their location? If we can find them and study them, is the knowledge gained sufficiently important or unique to justify the complexity and cost of working under the sea? Does it matter if we delay action, or do nothing?

There are several recently published books and conference volumes describing individual seabed prehistoric sites on the European and global scales (e.g. Flemming, 2004; Benjamin *et al.,* 2011; Evans *et al.,* 2014), including a database of over 2,500 submerged sites from the COST Action, SPLASHCOS[1]. Already we know that some prehistoric material on the sea floor can survive for more than 10,000 years on all kinds of seabed, rocky or sandy, steep or low gradient, sheltered or exposed. Amongst the thousands of sites that diving archaeologists and geoscientists have already found are submerged Mesolithic villages in the Baltic (Fischer, 1995; Harff *et al.,* 2007; Andersen, 2013), a cave with its only entrance at 40m below sea level and painting on the rock walls inside above sea level (Clottes and Courtin, 1994), flint fragments and worked tools from a site buried in sediments in the North Sea about 300,000 years old (Wessex Archaeology, 2011), a fragment of a Neanderthal skull from the North Sea (Hublin *et al.,* 2009), and early Neolithic villages at a depth of 15m in the sea off the coast of Israel, complete with fresh water wells, cooking hearths, organics, and hut foundations (Galili *et al.,* 1993). The human remains at Atlit off the coast of Israel are well-preserved so that the population age structure and mortality rates can be derived (Eshed and Galili, 2013).

Fig. 1.5 This beautifully carved Palaeolithic bone (11,000 yrs BP) from the floor of the North Sea illustrates the sense of decoration and pleasure which early hunters drew from their daily-used tools and weapons.

[7] COST Action TD0902 "Submerged Prehistoric Landscapes and Archaeology of the Continental Shelf" http://splashcos.org

Prehistoric peoples roamed over large areas to hunt for food and may have followed migrating herds of animals and changed their focus of activity with the season (e.g. Mol *et al.,* 2008). The whole terrain and landscape, including rivers, springs, caves, coastal lagoons, and the feeding grounds of large mammals needs to be understood if we are to recreate the way of life on the drowned continental shelf. Archaeological deposits on different land masses show that early hominins could cross water, at least by 50,000 years ago. The use of human genetic analysis and progressively more subtle comparisons of both modern and fossil DNA have provided greater detail of when people arrived in different areas, and thus by what date such crossings must have been made during periods of low sea level (e.g. Rasmussen *et al.,* 2014). But the precise routes by which migrations occurred, exactly when, the methods used, and how people lived in the transition area, require a combination of *in situ* archaeology and genetics. What we call “migrations” usually took place at speeds of less than 1km per year. Data from the seabed is the only way to resolve these uncertainties.


Credit: H. Dal

Fig. 1.6 Skull found on the floor of the Baltic at the Mesolithic site, Tybrind Vyg.

Protecting the cultural richness of the prehistoric continental shelf

As with archaeology on land, artefacts and remains from many periods can be superimposed or adjacent in the same region of the continental shelf, such as an Early Bronze Age town with a complex street plan located near a Palaeolithic flint-knapping site 50,000 years old. Furthermore, the excavation of more recent shipwrecks, which has been the most common form of marine archaeology to date, has occasionally produced prehistoric artefacts from the sediments below as a side effect.

Different geographical regions experienced different land subsidence or uplift due to the complex interplay between ice and water loading and unloading, and tectonic movements due to geological forces (see Chapters 2 and 5). As a result of this spatial and temporal variability, the relative local sea level curves need to be defined properly in order to establish where a shoreline was at any given time interval and where best to survey to locate remains that were on dry land at any given date. The extreme examples will be uplifting coasts, where Mesolithic sites can be found at sea level or even above, and strongly subsiding coasts where all the remains lie deeper than the depth at which they originally formed.

Prehistoric deposits have accumulated during multiple changes of sea level through successive glacial cycles (Dix and Westley, 2006), and are now threatened by the natural processes of tidal current erosion and mass wasting in open water, and especially by coastal erosion and retreat in the littoral environment. In addition to natural processes, human activities also threaten these deposits, including offshore industries such as dredging, bottom trawling, cable and pipe-entrenching, and wind-farm construction.

While the frequency of discovery of seabed prehistoric sites is increased by industrial activity (Peeters *et al.,* 2008; Borst *et al.,* 2014), provided that chance finds are reported, the sites that are revealed must be protected and studied. Proper codes of practice, reporting of finds, and collaboration between industries and cultural heritage agencies are key and should be incorporated in broader frameworks for Marine Spatial Planning. By education, publicity, and collaboration it may be possible to reduce the delays and economic costs which would otherwise occur, and maximize the protection of sites, while promoting tourism and public understanding.

Given such a range of component topics and disciplines, this report is bound to compress and summarize technical details, and to rely heavily on references and highly analysed and processed information. Thanks to decades of marine geoscience research, there are many such sources which provide useful maps that can help to develop reliable landscape reconstruction and statistics.

From Deukalion and SPLASHCOS to SUBLAND: a progressive transition from earth sciences and humanities interactions to deliver recommendations for a recognized research topic

In July 2008, a group of experts, the Deukalion Planning Group, was set up at the Third International Congress on Underwater Archaeology (IKUWA3[2]) (Annex 2) to convene regular meetings and consider long-term strategic plans and research opportunities. The concept of Deukalion is the first of its kind and led rapidly to an expansion of the network. In 2009, the Deukalion Planning Group successfully applied for a four-year (2009-2013) COST action which was entitled SPLASHCOS.

The SPLASHCOS action aimed to promote research on the archaeology, climate and environment of the submerged landscapes of the continental shelf, and more specifically to "improve knowledge on the location, preservation conditions, investigation methods, interpretation and management of underwater archaeological, geological and palaeoenvironmental evidence of prehistoric human activity, create a structure for the development of new interdisciplinary and international research collaboration, and provide guidance for archaeologists, heritage professionals, scientists, government agencies, commercial organizations, policy makers and a wider public." The completion of SPLASHCOS has provided a wealth of detailed information on thousands of known prehistoric sites in the sea, and supported the establishment of an extended community of almost 200 scholars engaged in Continental Shelf Prehistoric Research. An important follow-on priority is the need to integrate these data into a continuous interpretation or synthesis with the land-based data on prehistoric sites.

[2] http://www.nauticalarchaeologysociety.org/sites/default/files/u9/IKUWA3_programme.pdf

[3] http://www.european-archaeological-council.org

In order to cope with the broad spread of component disciplines and the need for combining expertise, analysis, and experience of field work, the European Marine Board decided to support a working group on submerged landscapes (WG SUBLAND, 2013-1014) with a view to delivering a position paper designed to embed the topic as a recognized research discipline at European level. One of the necessary functions of Continental Shelf Prehistoric Research is to share, and where possible integrate, the knowledge and experience of the archaeologists, technologists, and marine geoscientists. Therefore, the WG expert nomination was made in collaboration with the Europae Archaeologiae Consilium, or European Archaeological Council (EAC)[3], the members of which have provided valuable information on policies and procedures at the national level.

Continental Shelf Prehistoric Research requires a balanced and iterative relationship between the earth sciences and archaeology including the cultural interpretation. The questions raised by trying to understand the human response to changes in climate and the bio-geographical environment force us to examine the available data in a way which is not in line with the normal objectives of the earth sciences. Data collected for other purposes can be re-structured and re-interpreted, with new correlations, to define aspects of the palaeo-environment which would otherwise never have been detected. Traces of evidence derived from human cultures will provide paleoenvironmental information much more detailed than singular reference data on pollen, morphology or fossil remains. Ice modelling and glaciological models can be refined to examine the periglacial environment within which megafauna could have been hunted by humans. Complex geophysical models of the crustal response to the alternation of loading and offloading of ice and water can be run with the objective of reconstructing coastlines and the coastal plains and then ground-truthed with real data derived from the location of settlements or from the appearance and disappearance of migration routes. Sub-bottom profile acoustic data obtained from commercial prospecting can be reconstructed to reveal buried river valleys, lakes, and deltas. These new analyses then feed back into refined versions of the earth science understanding of the continental shelf and climate change during the glacial cycles. The accuracy and resolution required to detect prehistoric signals are very high, and far greater than that usually required in industry or geological mapping. In this context researchers from the humanities may be over-optimistic about what remote-sensing instruments can provide, and may be surprised by the amount of time taken in preparing technical projects, as well as by the time lost through bad weather at sea.

[4] EU Council Decisions 2013/743/EU, OJ L347, 20.12.2013, p. 1022.

[5] EU Council Conclusions on cultural heritage as a strategic resource for a sustainable Europe at Education, Youth, Culture and Sport Council meeting, Brussels, 20 May 2014.

1.2 Policy context

Cultural heritage assets are unique and are a major driver of societal cohesion, identity and well-being[4]. The Council of the European Union recently adopted conclusions on cultural heritage as a strategic resource for a sustainable Europe[5] and invited the European Commission to further support networking and promoting projects aimed at fostering sustainable management of cultural heritage. Horizon 2020, the new €80 billion EU programme for Research & Innovation aims to address societal challenges and support economic growth in Europe. "Societal Challenges" (SC) is one of the pillars of this solution-oriented programme, and Continental Shelf Prehistoric Research is relevant within SC2 "Food security, sustainable agriculture and forestry, marine and maritime and inland water research bio-based industries and the Bioeconomy", where cultural heritage is listed as one of the six broad areas specified to be tackled, and SC5 "Climate Action, Environment, Resource Efficiency and Raw Materials", which includes the Blue Growth Call, aiming to unlock the potential of seas and oceans.

Climate change and increased competition for space in the marine environment are seen as key problems requiring a response. On land, the need to protect archaeological deposits and cultural heritage is a fundamental tenet of the planning systems of most countries, but these factors are at present marginalized on the seabed. Environmental Impact Assessment (EIA) is deemed to include impact on fauna, flora, human beings, soil, water, landscape, and cultural heritage (Directive 2011/92/EU, European Parliament and Council, 13th Dec 2011, Article 3), and this Directive is not restricted to the land. The "Ecosystem Approach" to marine management requires multi-factorial assessment of a complex situation in advance, and the prediction of how numerous species and the sea floor itself will respond to the consequences of a given action or policy. Many of the observations needed to make such assessments, especially with regard to benthic communities, are similar to those required in the initial stages of remote sensing for Continental Shelf Prehistoric Research, especially in terms of describing habitats, substrates, and submerged landscapes. Significant efficiencies could be achieved by planning and implementing these two kinds of surveying together. The "Ecosystem approach" has been interpreted rigorously to exclude Cultural Heritage, and this is understandable since the term is used in Treaty documents. However, the exclusion of Cultural Heritage from broad-based multi-disciplinary surveys and mapping programmes of the sea bed no longer makes sense. A report[6] by the Advisory Group for Horizon 2020 SC5 debates this anomaly in detail, referring to the need for trans-disciplinarity, the role and potential of cultural history, the importance of the "Human-Earth-System" for understanding climate change, and the necessity of including cultural heritage when designing "Nature-Based-Solutions". These discussions are not concluded yet, but they indicate a pragmatic and theoretically sound way of including cultural heritage as a component in seabed management and research in Horizon 2020.

The EC DG MARE initiative on Marine Knowledge 2020[7] is an EU-level action to promote more effective access and multiple use of marine data. Its data portal, EMODnet, and its advisory group, the Marine Observation and Data Expert Group (MODEG), have received reports to consider ways of incorporating Continental Shelf Prehistoric Research data, especially submerged landscape data, in an integrated way with seabed geological and bathymetric data.

6 First Report of the Horizon 2020 Advisory Group for Societal Challenge 5: "Climate Action, Environment, Resource Efficiency and Raw Materials", pp. 31.

7 Green Paper Marine Knowledge 2020 from seabed mapping to ocean forecasting COM(2012) 473

[The European Parliament] Urges the Commission to help Member States launch plans to map and survey wrecked ships and submerged archaeological sites, which form an important part of the Union's historical and cultural heritage; stresses the need to facilitate the understanding and study of such sites and help prevent the despoliation to which they are being subjected, thus enabling them to be properly preserved.

European Parliament Report on Blue Growth (A7-0209/2013)

The objectives of Continental Shelf Prehistoric Research are consistent with the proposed directive for establishing a framework for Maritime Spatial Planning (MSP) (EC COM 2013). There is repeated emphasis on forward planning, anticipation of conflicts of use, sustainability, and the avoidance of regulatory surprises for offshore operators and managers. The phrase "ecosystem approach" is used frequently, with references to the objective of a sustainable environment, but this is defined in such a way as to make no reference to cultural heritage or archaeology.

The development of Continental Shelf Prehistoric Research is essentially conducted at the scale of marine basins, since prehistoric foraging, hunting and collecting/ harvesting ranged across the open plains, and coastal exploitation of resources followed fossil shorelines with no respect for modern national boundaries of jurisdiction. It is, therefore, a subject that intrinsically encourages collaboration of coastal states around sea basins. The Marine Research Plan of European Atlantic Sea Basin (SEAS-ERA, 2013) produced jointly by the national Research Funding Organizations (RFOs) through an EU FP7 SEAS-ERA project has listed an indicative enabling action to produce *"an inventory of European Atlantic maritime culture and heritage, including submerged artefacts and submarine landscapes"* under the category "Ocean Heritage." This clearly shows that the research funding agencies of the Atlantic margin countries recognize the need for, and importance of, Continental Shelf Prehistoric Research, but this has yet to be reflected in increased funding on such research.

National legislation has already been implemented in several countries, e.g. UK and France, to define the objectives and legislative role of Maritime Spatial Planning, and although national heritage agencies are well aware of their offshore responsibilities, this does not always result in that priority being included in MSP. In the UK the extensive areas approved for the development of offshore wind farms have stimulated detailed surveys of the impact on both shipwreck archaeology and submerged prehistoric landscapes (Marine Management Organisation, 2013). The East Inshore and East Offshore marine plans[8] (Marine Management Organisation, 2013) specifically refer to submerged landscapes, prehistoric remains, and the need to manage prehistoric and cultural heritage in the region of Dogger Bank. The Council for British Archaeology has published a national research agenda for Maritime Archaeology which includes chapters analyzing the offshore research requirements for Palaeolithic to Bronze Age submerged landscapes (Ransley *et al.,* 2013).

[8] http://www.marinemanagement.org.uk/marineplanning/areas/documents/east_draftplans.pdf (p.31 et seq. and para 117)

1.3 About this position paper

This position paper describes a new research field, **Continental Shelf Prehistoric Research.** The objectives of the position paper are to assess the present level of commitment to this research and to cultural heritage management in general, evaluate the results so far, consider the benefits, and plan ahead to justify further investment and collaboration at the European level. Both challenges and opportunities for future progress are identified and recommendations for future research are proposed which span technology, socio-economic benefits, research objectives, institutional infrastructure, training, and possible sources of funding.

The term "continental shelf", as defined by geologists and as used in this position paper, is the area of the seabed extending out from the shore to a depth of 120-150m surrounding the major continents and large islands of the world. It is the prolongation of continental crust which happens, at present, to be covered by shallow seas, but has often in the past been exposed as dry land. The outer limit is defined by the break of slope, which then descends more steeply to the deep ocean. In this position paper we are not referring to the complex legal definition of continental shelf jurisdiction used in the United Nations Convention of the Law of the Sea (UNCLOS) Article 76 which extends much further to the bottom of the continental slope, adjacent to the deep ocean floor. Since the UNCLOS decisions regarding states' continental shelf jurisdiction apply to a wider area than that considered in this paper, it is logical that they do also apply to the geological continental shelf as defined here (Further discussion in Ch.2).

The position paper is structured as follows:

- An assessment of the current situation, including achievements, structures of the research community, key scientific issues, interaction with industrial stakeholders and the legal background of laws and treaties (Ch.2);

- An examination of the available resources and the range of agencies and institutions involved in different countries. A survey of European agencies was conducted as part of the working group activities and provides quantitative data on research policy and management priorities. (Ch.3);

- A discussion to address issues on inherent problems, such as site protection from climate change and industrial activities, lack of high resolution seabed maps, shortage of human capacity building and a misconception that prehistoric sites were destroyed by the post-glacial rise of the sea. Concerning the latter, erroneous text can still be found in most archaeological text books and monographs and has confused efforts to implement consistent policies. This naturally deters the interests of students, and undermines the intentions of administrators (Ch.4);

- The diverse characteristics of different European seas determine past occupation, relative change of sea level since the Last Glacial Maximum, and varied oceanographic conditions. The requirements of each European sea basin are discussed in Ch.5;

- Chapter 6 focuses on the challenges in future technology development. There is still no acoustic technology to detect and locate prehistoric anthropogenic materials on the sea floor remotely, for example to distinguish scattered débitage of broken flints from natural gravel, or a piece of wood that has been cut and shaped from a natural log. Optical observation can make such distinctions, but the range of accurate vision underwater is only a few metres in ideal conditions, and usually much less;

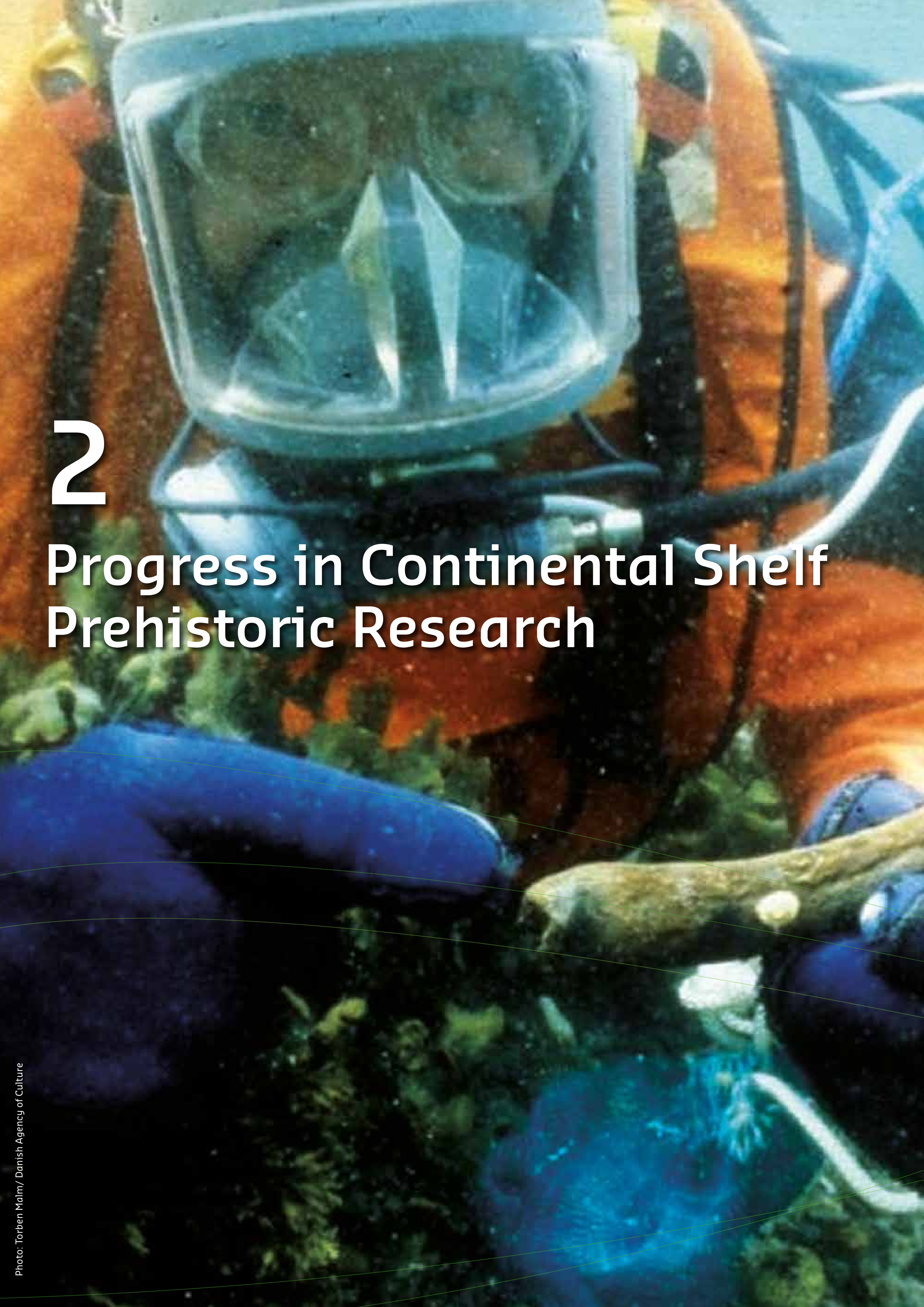
- Chapter 7 summarizes the recommendations of the working group which should form the basis of a future research programme on Continental Shelf Prehistoric Research. The origin and evolution of human occupation of the European continent cannot be fully understood without research into the prehistoric sites and cultures on the continental shelf.

SUMMARY

A recognized new research field, Continental Shelf Prehistoric Research, should be established, in science, academy, and public awareness, with support for new publications, websites, popular exhibits, museums, tourist displays, and a definitive entry on the subject in Wikipedia.

There is some urgency to make progress as archaeological relics are eroding away.

- A long-term integrated approach is needed.
- Trans-domain collaboration between disciplines and agencies is essential.
- Collaboration with industry is important.
- Europe is amongst the global leaders in this field.
- The SPLASHCOS data base should be continued and linked to EMODnet.
- The SPLASHCOS community should be consulted to establish a conference series and regular outlets for publications.
- In addition to collaboration between prehistoric archaeologists and marine geologists, interdisciplinary research will need to engage palaeoclimate researchers and modellers, geophysical engineers, and the DNA genetics research community.



2

Progress in Continental Shelf Prehistoric Research

Photo: Torben Malm/ Danish Agency of Culture

2.1 Scientific achievements

Climate change, sea level variations and landscapes

Most of the European continental shelf was exposed by the lowering of global sea level many times during the last one million years, and this vast and dry area was occupied by vegetation and animals, including anatomically modern humans (AMH) and their precursors, collectively known as hominins. Part of the exposed shelf in northern Europe was covered by the ice caps and was, therefore, not available for occupation, but the extent to which people lived close to the ice and exploited the peri-glacial megafauna is still uncertain. We cannot understand the whole story by studying only the present dry land record and ignoring the now submerged seabed of the continental shelf. Did the fluctuating climate zones and migrating coastlines and river valleys influence where people lived? Did the falling and rising sea level create cultural experiences and responses that are still felt or had impact in the historic world of writing and oral history?

Image: NASA World Wind/Sea Level add-on

Fig. 2.1 A simulation of the impact on the coastal lands of Europe today if the sea level rose by 120m. This is not a prediction, but a visual demonstration on how much the landscape would alter and how familiar regions could disappear under the sea.

Although the rise of the sea after the last glaciation took about 15,000 years, the change would nevertheless have been perceived as a continuous retreat of the shoreline and loss of land which was quite noticeable in one generation. Given the fertility of coastal plains, both for the terrestrial fauna on grasslands and resources in marshes, deltas, and wetlands, the continuous loss of such land must have been an unfortunate aspect of life in the Late Palaeolithic and Mesolithic periods. However, it should be noted that a rising sea level would occasionally inundate an area of low gradient such as the North Sea basin, or the Adriatic seafloor, creating massively extensive new marshlands and new environments which could support adapting coastal and aquatic life styles. Populations certainly moved and adapted in response to such change of climate and sea level and there is a need for significant further research to track these movements. In order to understand where people could live and hunt or forage in the European area at different dates and different stages of the glacial-deglacial cycles, we need to analyse the details of sea level change and ice cap limits through time.

Diving archaeologist collecting a red deer antler at a Danish Mesolithic site (Rønsten site, ca. 7,500 yr cal BP, 1-3 m of depth).

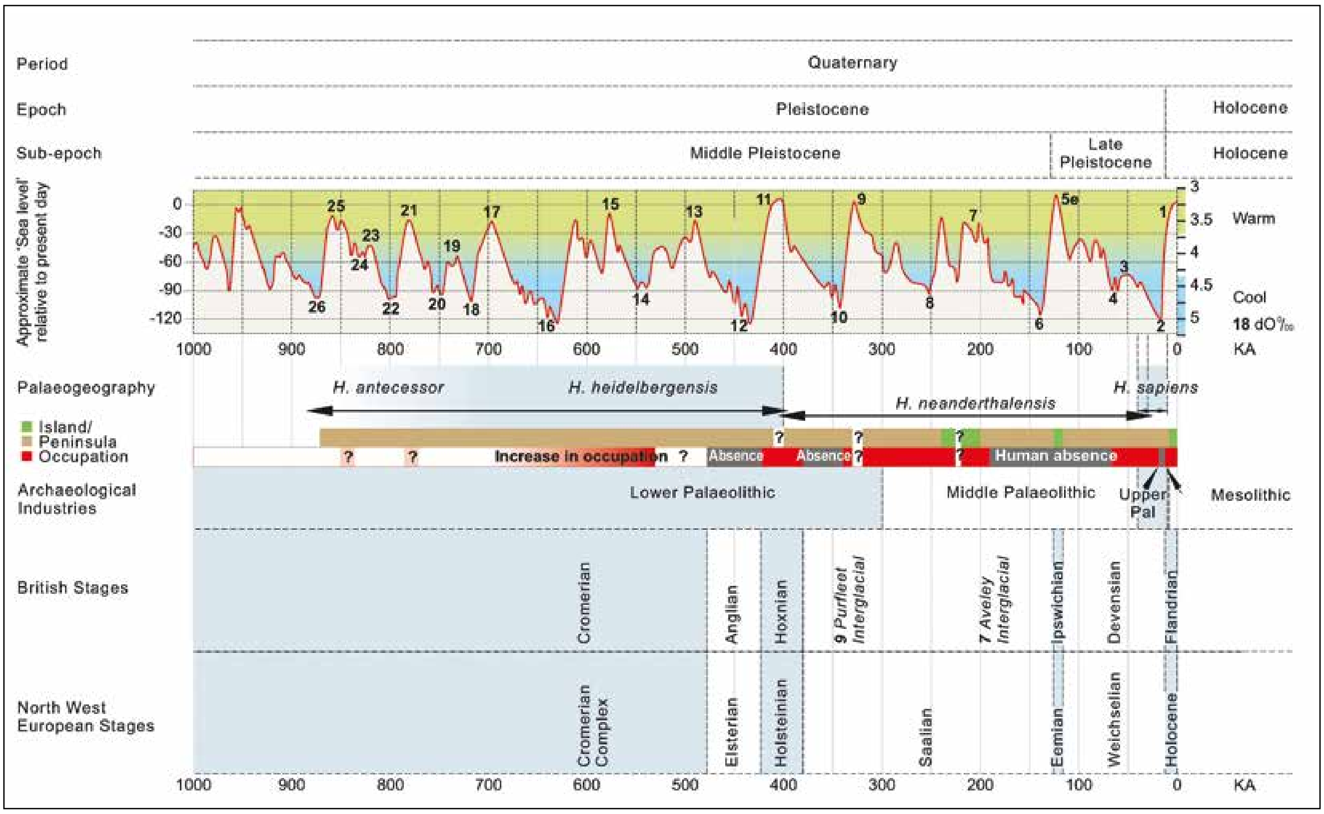
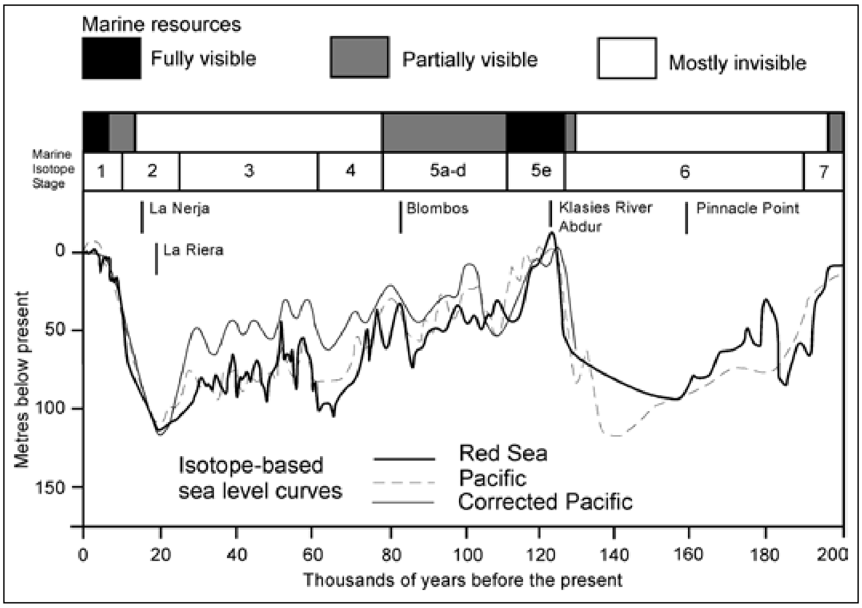


Fig. 2.2 Global sea level change during the last 1 million years in the southern North Sea, combined with the sequence of hominin-human ancestor species, archaeological stone age industries, and British site names given to different local stone age industries. The numbers on the sea level curve refer to the marine oxygen isotope sequence derived from deep ocean sediment cores (Shackleton and Opdyke, 1977). (Wessex Archaeology, 2011) (Note: increasing time to the past goes from right to left).

Fig. 2.3 Simplified sea-level curves for the past 200 ka (Bailey and Flemming, 2008), showing archaeological sites with evidence of human use of marine resources in different parts of the world. The Red Sea and Pacific records are derived from ∂[18]O measurements of benthic foraminifera. The corrected record is based on corrections derived from elevated coral terraces and based on a number of sources. (Note: time past increases from left to right)



Because of the complex topography of the European coastlines with several semi-enclosed seas and the proximity of the northern ice mass, the dry land area in the past cannot be derived from modern depth contours or isobaths. The mechanism, by which the earth's crust responds to the global redistribution of mass during the freezing of an ice cap, the lowering of sea level, and then the reverse process, is called Glacial Hydro-Isostatic Adjustment (GIA). The computations to reconstruct the state at different dates are made based on the assumptions of the mass of ice, rheology of the crust and mantle, and volume of sea water (Shennan *et al.,* 2006; Antonioli *et al.,* 2006; Lambeck and Purcell, 2001 & 2005; Peltier *et al.,* 2002; Spada and Stocchi, 2007).

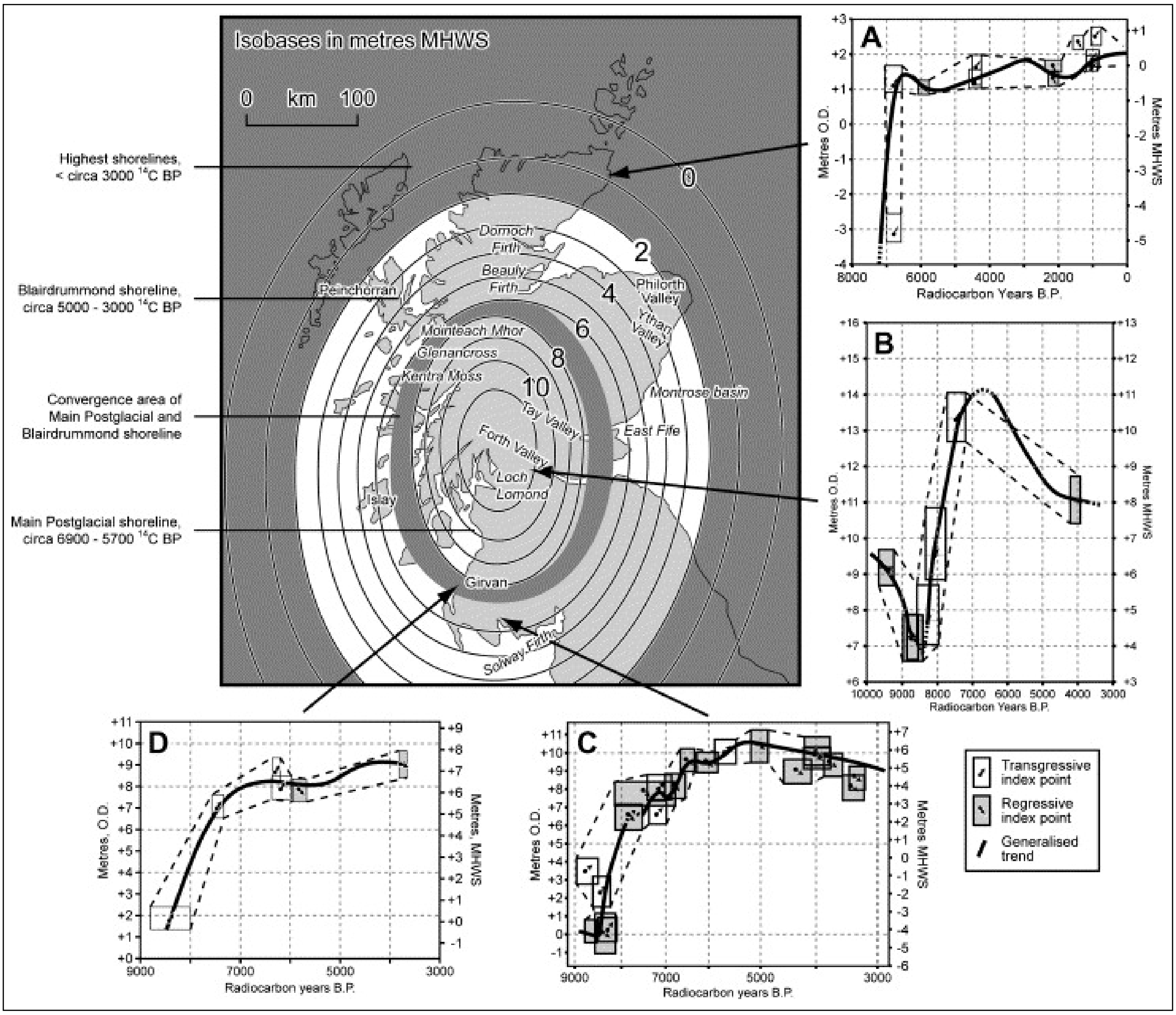
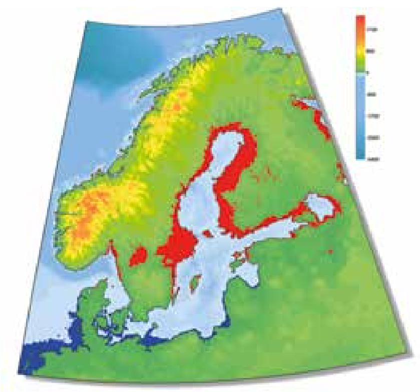
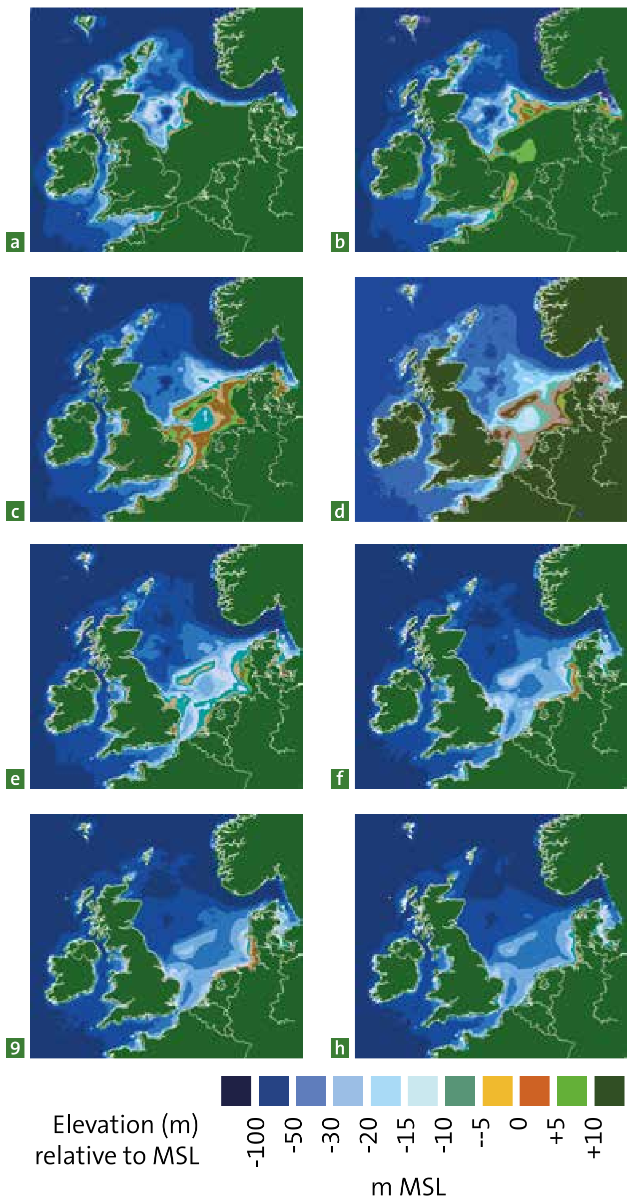


Fig. 2.4 Relative sea level change across the Scottish postglacial uplift zone (Smith *et al.,* 2007). Because the ice caps on Scotland and Scandinavia were smaller and melted faster than those of Greenland, Antarctica, and North America, the land which had been depressed under the weight of ice rebounded faster than the rise of global sea level. As the local land uplift slowed down, the raising global sea level overtook it in most places, and produced a reversal of relative sea level. Analysing this problem at a scale and resolution that permits the reconstruction of palaeo-shorelines and exact definitions of the ice edge at each date would greatly facilitate the understanding of Continental Shelf Prehistoric Research.

Calculation of local climate and environmental conditions, and hence living conditions, at different stages of the glacial cycle requires degrees of accuracy and resolution in GIA computations which are only now becoming possible. In recent years the GIA community has extended the complexity and realism of numerical models by implementing mutual feedbacks between cryosphere, solid Earth, oceans and sediments (Gomez *et al.*, 2012; Gomez *et al.*, 2013; Dalca *et al.*, 2013; de Boer *et al.*, 2013). European modellers are pushing forward the state of the art of ice-sheets and GIA-sea-level modeling by dynamically coupling ice-sheets to self-gravitating and rotating Earth models with realistically varying topographies and self-consistent adjustments of the ocean flow (Rugenstein *et al.*, 2014). This new generation of GIA numerical systems will serve as a set of tools to reconstruct the climate-related geographical changes that forced human evolution. Recent findings about the implications and effects of eustatically-driven surface-area variations of islands on species distribution patterns (Rijsdijk *et al.*, 2014) will be therefore significantly improved once the simple eustatic concept is abandoned in favour of GIA-driven sea-level changes.

Fig. 2.5 The Baltic Sea was isolated as a lake in two separate phases during the last rise of global sea level. Change of coastlines of the Baltic Sea since the beginning of the last marine stage (Littorina Sea) at about 8,500 cal yrs BP demonstrated competition between Holocene sea-level rise and isostatic land uplift (after Harff *et al.*, 2007). In the figure, the blue colour mark areas of land lost due to marine transgression and red colour areas of land gained due to regressive shore displacement. In the transitional zone drowned terrestrial landscapes are dated only to earliest part of the Littorina Sea (before c 7,400 cal yrs BP) while younger landscapes and settlement sites are on the land. Finally, as seen today, the northern Baltic coast is still rising relative to sea level, while the southern coast is sinking.

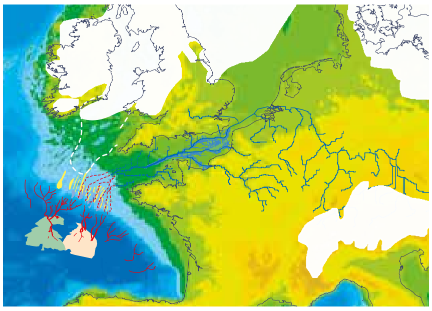




Credit: Geological Society of London

Fig. 2.6 For the north-west European continental shelf the post-LGM uplift of Scotland and the northern North Sea floor created at first an enlarged area of exposed continental shelf as it rose faster than the global sea level. Then as global sea level rise accelerated, the shelf area from France to Norway, embracing all the British Isles, was progressively inundated. Like the northern Baltic coast, most of Scotland is still rising relative to sea level. Figure shows the sequence of inundation of the European NW shelf, taking into account the compensatory earth movements from glacial hydro-isostatic adjustment (Shennan *et al.*, 2000): (a) 10,000 (b) 9,000 (c) 8,000 (d) 7,500 (e) 7,000 (f) 6,000 (g) 5,000 and (h) 4000 years BP. Elevations and depths are in metres relative to sea level at each date.

Since access to freshwater, and possibly the food sources of fish and shellfish, was an attraction both for humans and other animals, it is valuable to identify and plot in detail the courses of the main river valleys and their minor tributaries on the exposed continental shelf. The discharge of rainfall and meltwater from collapsing ice sheets through the southern North Sea and through braided river valleys on the floor of the English Channel has been intensively studied (Lericolais *et al.*, 2003; Toucanne *et al.*, 2009).



Credit: J-F Bourillet

Fig. 2.7 Channel River drainage pattern in the southern North sea and English Channel (La Manche) at the last glacial maximum, 20,000 years ago (Bourillet *et al.*, 2003).

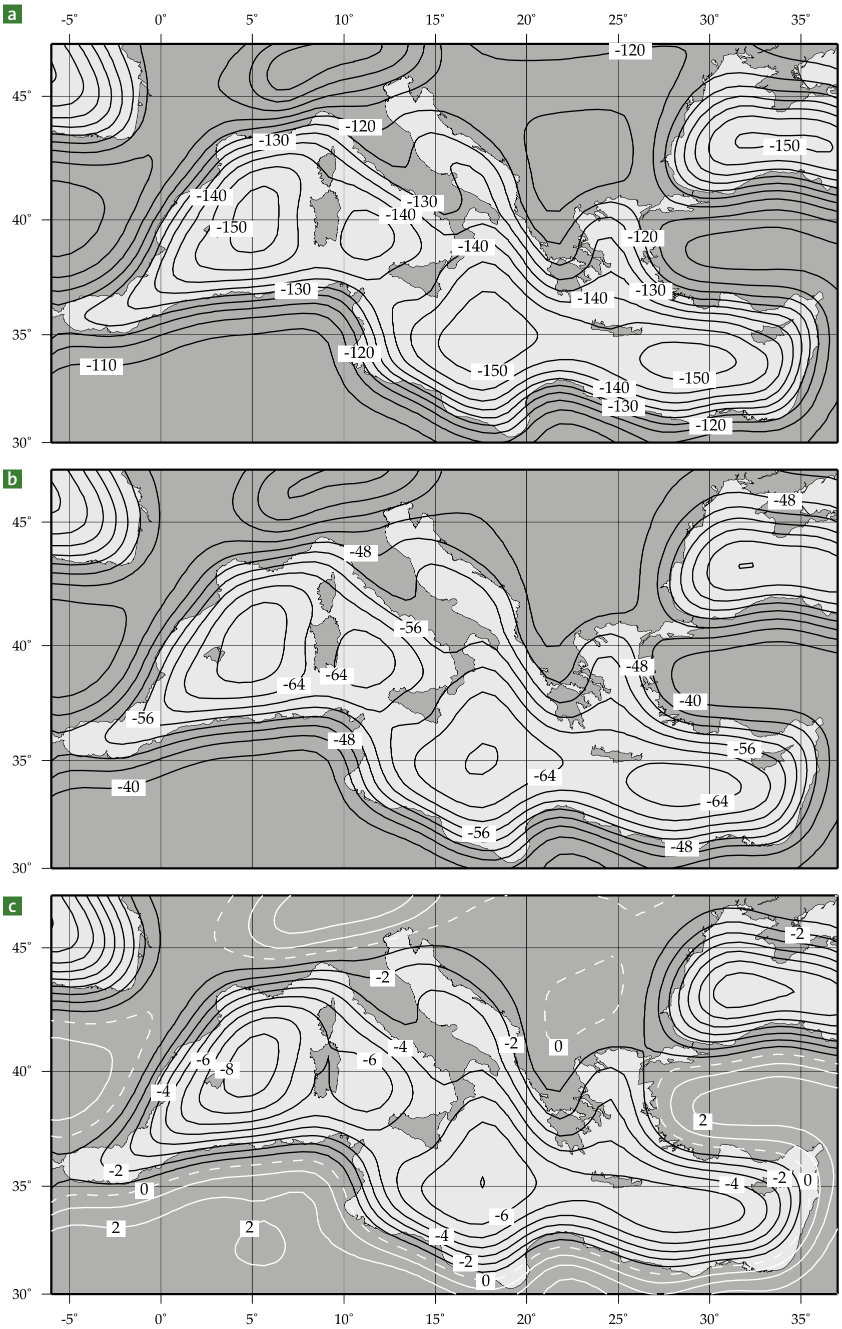


Fig. 2.8 In the Mediterranean, far from the immediate effects of the ice cap, the addition and subtraction of over 100m of seawater caused the basins to sink and rise during glacial and interglacial periods. Figure shows the net effect of post LGM sea-level at 20, 12, and 6 ka (Lambeck and Purcell, 2005).

Almost everything that we do know about Palaeolithic cultures derives from settlements that are now on land, and that were tens to hundreds of kilometres distant from the coastline when they were occupied. Because of the post-glacial rise of the seas, we know almost nothing about the wide, nearly flat fertile land exposed by the lower sea level, suitable for collecting and gathering resources, for coast-wise migration, and the development of specialize maritime settlements. If we go back in time several glaciations the uncertainty becomes greater.

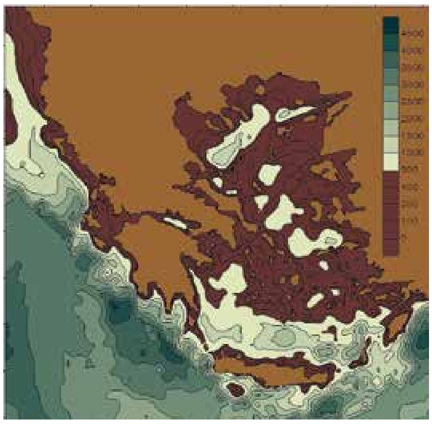


Fig. 2.9 The Mediterranean is active in terms of plate tectonics and volcanism and the derivation of the areas of dry land at different dates must take into account the global sea level change, the regional Glacial Hydro-Isostatic Adjustment, and the vertical changes caused by tectonics. This calculation by Lykousis (2009) shows the Aegean at 400,000 years ago, and suggests that hominins could have migrated from the Levant coast to southern Europe without crossing water.

The role of geoarchaeology

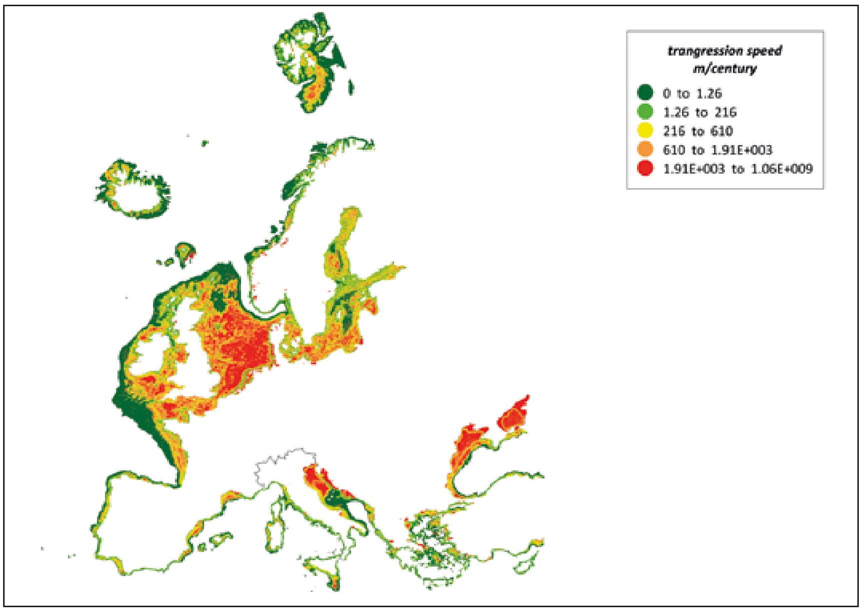
Understanding the survival or destruction of submerged sites is fundamental to the progress of Continental Shelf Prehistoric Research. Geoarchaeological processes determine the burial of the site on land, or its erosion, its response to wave action during inundation, and the subsequent oceanographic forces on the site and its place in the sedimentary column (e.g. Waters 1992; TRC Environmental Corporation, 2012). SPLASHCOS established a working group to analyze the geoarchaeological survival of submerged prehistoric sites and is devoting a book to this subject (Flemming *et al.,* 2015, in preparation).

The analysis of geoarchaeological processes, combined with the distribution of submerged prehistoric sites that have been discovered, shows that prehistoric indicators can survive in a great variety of conditions and on all coastal types. As the original deposits may have been disturbed or scattered, the artefacts are sometimes found in rock clefts or river gravels. Knowledge of local geology and oceanographic conditions should be synthesized to provide information on the typical environmental conditions for possible survival sites (See Chapter 5), such as for steep rocky coasts, sandy coasts, archipelagos, basins with continuous sediment accumulation, estuaries and rivers etc. An example of such a synthesis is provided by Peeters and Cohen (2014) for the North Sea. The distribution of sites found so far indicates a greater frequency in areas of low gradient, limited wind fetch and gradual sediment accumulation, although sites do occur on all types of coast and shallow shelf.

The effect of the rate of sea level rise and horizontal marine transgression on site survival has attracted considerable debates (Belknap and Kraft, 1981; Waters, 1992; Andrew *et al.,* 2004; TRC Environmental Corporation, 2012). The average rate of sea level rise post LGM from 20,000 to 6,000 BP was about 1 cm/year, but at a varying velocity. It was very slow at the beginning and at the end of the rise (for instance the sea level in the last 2,000 years rose with an average rate of 0.1 mm/year). In contrast, periods of fast sea level rise (melt-water pulses linked to abrupt input of freshwater produced by melting glaciers) are recognized worldwide reaching rates up to 3-4 cm/year. These figures are modified regionally by the uplift/subsidence of the coast due either to tectonics or post-glacial isostatic readjustment of the Earth's crust, and by regional gravitational effects caused by the mass of ice (Stocchi *et al.,* 2013). The rise of sea level caused the shoreline to move inland, and the rate of horizontal movement landward is called marine transgression. In the process the land may be simply flooded over or partially removed by erosion. The horizontal velocity of the transgression is a combination of the rate of sea level rise and the local gradient of the topography, with slow sea level rise and high-gradient topography causing a low transgression velocity, while high velocity transgression is produced by fast sea level rise coupled with low-gradient topography (Fig. 2.10). The two factors can be combined so as to compute a map of the rates of transgression for each part of the

European continental shelf as the sea rose, showing that some areas experienced a horizontal rate of 2km per century and others less than 1m per century.

The likelihood of a prehistoric site being preserved from erosion during transgression is not only dictated by transgression velocity. Other factors play an equally important role, such as the sheltering of a site from incoming waves by local outcrops or lagoons, or the type of deposit where the site is embedded or buried. However, the rate at which the surf-zone transited over the site is linked to the number of major storms that the coastline experienced, the total amount of erosion it may have suffered, and thus the probability that even the most secure protecting barriers will be broken down. This process highlights the need for reliable sea level curves and detailed topography for Continental Shelf Prehistoric Research.



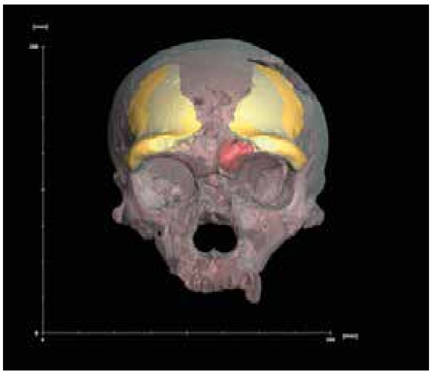
Graphic and computation: F. Chiocci

Fig. 2.10 Rate of horizontal marine transgression across the European continental shelf in metres per century. This plot is obtained by combining the curve for post-glacial sea level rise with the present topography of the sea floor.

The mapping survey, and possible excavation of submerged relics from prehistoric coastal sites can tell us about the climate in which the people lived, their migration routes into Europe, the food they ate, their exploitation of marine resources and seacraft tens to hundreds of thousands of years ago, their response to changing climate and rising or falling sea level, and their response to the fluctuating margins of the great ice caps. At the same time it may provide Quaternary geologists with very fine details about regional climate change using multiple dating techniques and interlocking cultural and geochemical indicators.

Seabed prehistoric sites: progress so far and potential for collaboration

It was already known more than 100 years ago that prehistoric human communities had lived on what is now the continental shelf, but it was not until the 1950s that it became possible to consider proactive intervention on the seabed. All finds were random, arising from fishing or dredging. The finds were intellectually recognized and understood, but scientists and archaeologists were helpless to exploit them through planned research at sea. Maps, survey techniques, and understanding of coastal processes and the Quaternary glacial cycles were all insufficient to justify expenditure focused on finding or studying submerged prehistoric sites, let alone integrating them into palaeo-landscapes.



Credit: J.J. Hublin

Fig.2.11a The duration of pre-human occupation of the North Sea basin extends back hundreds of thousands of years, and requires study by collaborative groups from all coastal North Sea states. A single fragment of Neanderthal skull was found in Dutch waters. This image has been made by using the fragment twice, once reversed. (Hublin *et al.,* 2009).

Borst *et al.*, 2014

Fig. 2.11b Reconstruction of a human skull with two 9,600 year-old pieces found on the artificial beach of Maasvlakte 2. Originally, they come from the dredging area some 10 km offshore (Borst *et al.,* 2014).

SPLASHCOS (2009-2013) collected data on 2,672 submerged prehistoric sites from 19 countries[9], but the distribution and quality of the data differs from area to area. The coastal seas with the highest number of known sites are in the Baltic and Limfjord part of Denmark, Brittany (France), Southern England, the German Baltic coast and North-Croatia. Together the sites in these areas make up 85% of the sites in the database. The number of sites in Denmark alone is 64 %, which is a significant part of the total. Most of the 2,672 sites are characterized by single (61%) or a collection of finds (14%) salvaged on different occasions by fishing, drilling or diving. Also most of the other sites were primarily detected in that way, but could in the future be characterized and analysed by further scientific investigations. Only a few sites are identified as burials or depositions, but the great majority of them – 430 sites (16.1 %) – have been classified as settlement remains. Fireplaces, cultural layers and wooden structures were covered and then preserved by the sea over thousands of years. Thus the range of preserved material is often very different from that of contemporaneous sites positioned on dry land. Objects made of organic material like wooden fish weirs or tools made from antler, wood or bone are prominent in the inventory, whereas such materials are rarely found on land-based sites. Of high scientific significance is also a small number of extraordinary finds such as logboats, or palaeohuman remains, forming the base for excellent research on human evolution and migration as well as on the strategy of adaption to the changing habitat (Fig 2.11).

When it comes to the chronological range of the submerged sites around 30% of the sites detected so far can be dated only in a generalized way to the Stone Age or early prehistory because the artefacts salvaged from them do not allow a closer typochronological classification. The other sites may be dated at least to the Palaeolithic, Mesolithic and Neolithic periods; often with the possibility for a more precise classification into the early, middle or late phases. Artefacts from several sites indicate that they existed during phases of transition such as Late Mesolithic/ Early Neolithic. Following statistical analyses these sites were generally assigned to the older dating. The chronological setting of the datable sites is based in 95% of the cases on the typochronological classification of the artefacts. So far only 3.5% of sites are dated directly with mature scientific methods such as radiocarbon or dendrochronology; the remainder are chronologically classified with the help of regional or local sea level curves or by stratigraphy.

Comparing the percentage of the 1,713 submerged sites dated so far, big differences become obvious. Only 10% of them existed during the Palaeolithic period and represent the period of the first post-LGM human migration to Europe, or pre-LGM. These findspots are more or less equally distributed in European waters; a conspicuous higher density is only detectable in the North Sea around the southern part of the United Kingdom.

The largest share (53 %) of the datable sites can be classified as Mesolithic, and they cluster mainly in the southern Baltic Area and the waters of the United Kingdom. There are no reported Mesolithic finds from France, although there is a high density area of findspots. In addition, there are no known Mesolithic finds from the Mediterranean Sea. One reason for that might be that the process of Neolithisation already started there 10,000 cal. BP. directly following the late Palaeolithic, so that the Mesolithic period was very short or does not even exist in the chronological systems. (In Israel the classification system of Pre-Pottery Neolithic is used (16%)). In all, 420 recorded sites are dated to the Neolithic. They are generally more evenly

[9] Belgium, Bulgaria, Croatia, Cyprus, Denmark, France, Germany, Greece, Ireland, Israel, Italy, The Netherlands, Norway, Poland, Portugal, Sweden, Turkey, United Kingdom, Ukraine

distributed throughout most of European marine waters. This indicates that the coastal zone was still attractive as a habitat although agriculture had become the economic base for most communities. The relatively large number of known Neolithic sites in the Mediterranean may result from the stone built structures that are typical for this period. They can more easily be detected and identified by divers compared to a flimsy scattering of lithics that are typical of the previous periods.

The rate of discovery on the European continental shelf in recent decades has been astonishing. Current data (Fig. 2.12) show a reasonably dense distribution for the period 10,000- 5,000 years ago in some regions, and then a progressively sparser scatter as we go back in time, with very few sites before 20-30,000 BP, although the oldest site in European seas to date is 300,000 years old (Wessex Archaeology, 2011). Although SPLASHCOS has begun to systematize the reasons for the survival or destruction of prehistoric sites on the seabed, this research is still embryonic, and it is still not possible either to predict where a site should be, or whether it would have survived the process of inundation or not.

Through the discoveries of submerged prehistoric sites[10], we are learning rapidly from their contents: settlements, tool assemblages and scattered artefacts (more details in Chapters 3 and 4), but gaps in knowledge are still significant. On land the relatively dense spatio-temporal distribution of known sites indicates fairly reliably when people or cultures appeared in a given area, or evolved into a new life-style. Outside the Baltic, the sparse density of known sites offshore does not permit such analysis, especially for the earlier periods.

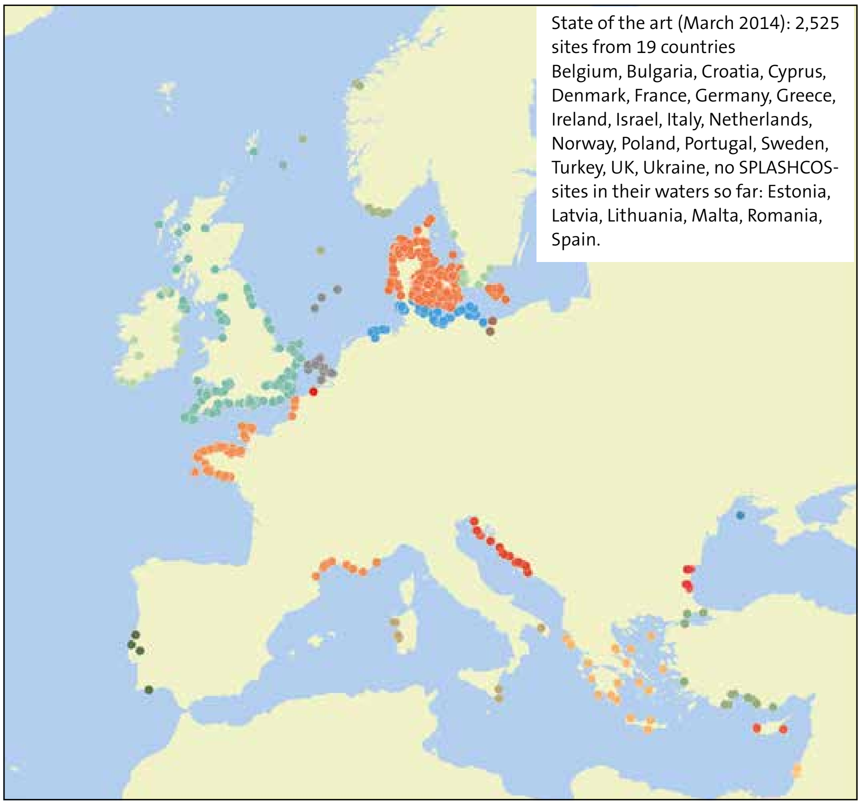


Fig. 2.12 Over 2,500 prehistoric archaeological sites have been discovered off the coasts of Europe. Some of the dots on this map indicate many tens of sites and artefacts within a few kilometres of each other (data collection organized by H. Jöns on behalf of the SPLASHCOS-network).

[10] A global map demonstrates the locations of marine prehistoric sites studied by European experts during the SPLASHCOS Action. https://mapsengine.google.com/map/edit?mid=z8tSvNpR3Nxc.kFeJ2yQqfoRg

One short-term objective is to quantify on archaeological grounds how many sites of different ages are needed to define with reasonable accuracy the status of hominin activity on the continental shelf at different periods, and the means to find and study them. This will facilitate future planning of focused research. The rate of discovery of sites has been increasing exponentially, but it may be necessary now to focus research on gaps in knowledge, rather than on studying more sites from well-known periods. The atlas of sites catalogued by SPLASHCOS is provided by Fischer and Bailey (2015, in preparation). The goal is to provide archaeologists with sufficient data to analyse, not just presence or absence, but population structures, diets, hunting strategies, mortality rates and cultural attributes, while human bones preserved at a low and constant temperature will shed light on ancient genetics and population dispersals by preserving the DNA.

The study of submerged prehistoric sites requires exploration technology and seafloor imagery. Systems such as technical diving (gas mixtures), mechanical (grabs and corers) and autonomous (ROVs/AUVs) instruments can increase exploration depth. High resolution mapping of features and sub-seafloor stratigraphy linked to archaeological settlements can also be obtained by acoustic systems (side-scan sonar and multibeam) and high frequency sub-bottom seismic reflection. Development of various advanced sensors opens the opportunity for recognition of material of cultural heritage value. (see Chapter 6).

Existing large-scale mapping programmes on the European continental shelf (INFOMAR[11], MAREANO[12], and MaGIC[13]) which focus on EEZ mapping, fishery and oil industry development, and geohazards, do not target archaeological studies, although they may provide useful information on the palaeo-landscape and palaeogeography of the continental shelf. The main agencies studying the seabed in most countries are the national geological services, which work with the hydrographic offices, and chart agencies, to study the solid geology, Quaternary sediments, and modern marine sediments on their continental shelves. These agencies provide information essential to marine archaeologists searching for or working on submerged prehistoric sites. National heritage agencies often have marine programmes and these are increasingly recognizing that the seabed prehistoric heritage is as important as ancient shipwrecks. The European Archaeological Council (EAC) has an Underwater Cultural Heritage working group.

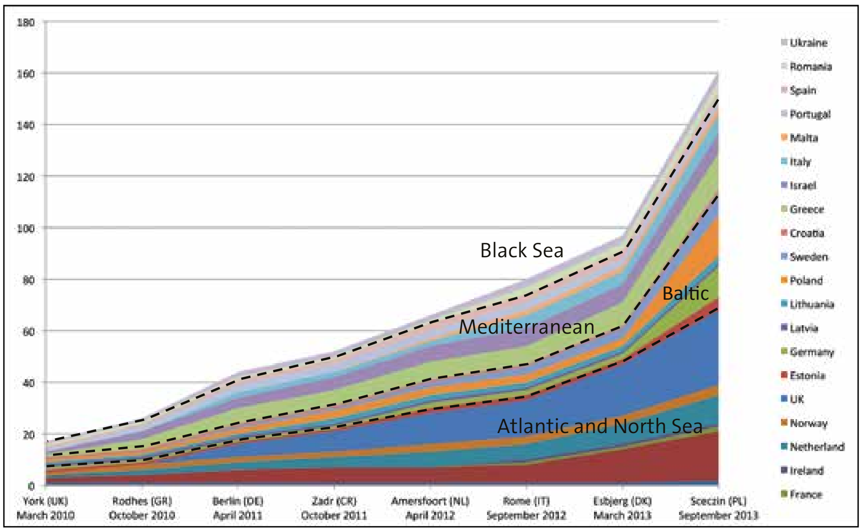


Fig. 2.13 Numbers of papers presented by different countries in the SLASHCOS meetings, 2010-2013.

[11] Integrated Mapping for the Sustainable Development of Ireland's Marine Resource http://www.infomar.ie/ - a successor to Irish National Seabed Survey (INSS) database

[12] Marine Area database for Norwegian waters (http://www.mareano.no/en)

[13] Marine Geohazards along the Italian Coasts (http://magicproject.it/)

Universities and regional or county museums sometimes have links to diving groups, or employ a small number of well-trained divers who can deploy their archaeological skills underwater. These connections and linkages are very beneficial, but ad hoc and inconsistent, often depending on the initiative of one key person.

Continental Shelf Prehistoric Research is gradually gaining global interest and support. The International Union of Quaternary Research (INQUA)[14] and the International Geoscience Programme (IGCP)[15] have, for decades, recognized and occasionally supported the human/hominin dimension in Quaternary/Pleistocene research, including the role of the continental shelf (e.g. Yim *et al.,* 2002), but not including the direct study of submerged sites. Similarly, major international conference series occasionaly hold a session on continental shelf submerged sites, as happened at the World Archaeological Conference[16] (WAC-6, Ireland, 2008) and the 34th International Geological Congress, Australia (IGC, 2012). The UNESCO Office for Underwater Cultural Heritage also recognizes the importance of the prehistoric continental shelf, and organized a Scientific Colloquium[17] (Brussels, 2011) on factors impacting underwater cultural heritage.

USA agencies and scientists are investing in surveys and assessment of prehistoric offshore potential on a large scale (e.g. TRC Environmental Corporation, 2012), and, as in Europe, the USA has a long past record of smaller individual projects. A recent US Bureau of Ocean Management project involved working with Narragansett Indian Tribal leaders to study submerged sites[18] .

During the second half of the 20th century the dating of the glacial cycles was established, including the magnitude of sea level fluctuations and the global crustal and mantle response to glacial/deglacial cycles (GIA) as described above (Shennan *et al.,* 2000; Lambeck and Purcell, 2001). Acoustic sea bed survey and sub-bottom profiling systems improved enormously and global climate modelling improved through the use of high resolution coupled ocean-atmosphere models. In every area of understanding of the Quaternary period the component sectors of knowledge have developed to the point where we can start searching logically for patterns of human occupation of the continental shelf, not only since the last glacial maximum (LGM) 20,000 years ago, but for earlier periods of low sea level as well. An essential component will be the application of modern computing power, data archiving and retrieval, and multi-component modelling. Modern availability of very large datasets from many disciplines, and the ability to handle, manipulate, combine, and visualize multi-source data, make it possible for the first time to integrate and analyze different hypotheses, bringing together the marine geo-sciences and the humanities. This is a rare opportunity, and the experience gained may be applicable in quite different fields.

The European research community involved in Continental Shelf Prehistoric Research is highly active, well networked and is growing steadily. The topic is appreciated by multi-national and international organizations, but support is very ad hoc and transitory. At the funding level, there is no European over-view or strategy, no infrastructure, and very little training or co-ordination of research. Planning Continental Shelf Prehistoric Research at the European level, rather than locally, includes the need to analyse each sea basin from coast to coast, integrating both the environmental and prehistoric archaeological factors which do not respect modern jurisdictional boundaries; the need to minimize research costs and exploit existing research resources such as mapping and data management at European

14 INQUA http://www.inqua.org

15 Launched in 1972 and originally termed as "International Geological Correlation Programme," is a cooperative enterprise of UNESCO and the International Union of Geological Sciences (IUGS). http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/international-geoscience-programme/

16 WAC: http://www.worldarchaeologicalcongress.org/; WAC-6: http://www.worldarchaeologicalcongress.org/site/wacpress_20.php

17 http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/dynamic-content-single-view/news/international_scientific_colloquium_on_the_factors_impacting_underwater_cultural_heritage_at_the_royal_library_of_belgium/#.U5AzAih-hS1

18 http://www.pbn.com/Next-frontier-in-tribal-research-is-underwater,90099

scale; the need to integrate Continental Shelf Prehistoric Research and the associated protection of cultural heritage with Marine Spatial Planning, and, where possible, standard or compatible regulations. It is logical to establish collaborative groups of laboratories and institutes working in cross-border maritime clusters.

2.2 Present interaction beyond academic communities

Stakeholders who share an interest in the good management of Continental Shelf Prehistoric Research include the professional agencies and educational establishments concerned with the study and protection of cultural heritage, a range of public and amateur bodies which have an interest in cultural heritage, including tourism, and those industries and recreational activities in the sea that share the marine space (Box 2.1). For example, the World Association for Waterborne Transport Infrastructure (PIANC) has recently published a code of practice for dredging and port construction which includes assessment of archaeological prehistoric sites and risks of their disturbance (Wessex Archaeology, 2014).

BOX 2.1 Stakeholders with a vested interest in Continental Shelf Prehistoric Research

Cultural heritage departments and agencies	Offshore hydrocarbon producers and service companies
Universities and marine institutes	Channel maintenance dredgers
Aggregate dredging companies	Sports divers and commercial divers
Coastal civil engineers, e.g. PIANC[19]	Amateur palaeontologists and fossil shops
Fishery companies and regulators	Basin-scale marine resource managers
Marine Spatial Planning agencies	Marine renewable energy sector

The increasing use of the continental shelf for cable routes, wind farms, sediment dredging (beach nourishment and land reclamation) and dumping (harbour maintenance), requires an assessment of the impact on cultural heritage. Local and national authorities need information in order to guarantee the correct management of activities and planning of infrastructures. While the need to protect shipwrecks is well known, the need to protect submerged prehistoric sites is not widely recognized.

Credit: T. Missiaen

Fig. 2.14 Searching the spoil of a dredger for possible recovery of stone tools from the floor of the North Sea.

[19]The World Association for Waterborne Transport Infrastructure. http://www.pianc.org/

Cultural heritage agencies and archaeological research institutions are the main beneficiaries of Continental Shelf Prehistoric Research as it will widen their knowledge of the hidden part of prehistoric archeology. The detailed information on palaeoclimate, plaeovegetation, palaeohydrology that may derive from Continental Shelf Prehistoric Research are of significant interest to specialists studying global change and climate evolution. But the benefits also extend to the industries and recreational activities using the sea and the general public.

Due to the increasing intensity of land use, watercourse damming and construction of coastal defence and harbour structures, many of the European sandy shorelines have experienced a shift from coastal progradation to coastal retreat. As a consequence, coastal prehistoric sites that were buried by sedimentation within coastal plains are now exhumed by wave erosion and exposed at the seafloor. As an example, the winter storms of 2013-14 exposed prehistoric remains, drowned forests and submerged peat beds on many parts of the British and Irish coasts (Fig. 2.16). There is an urgent need to identify, document and possibly protect such structures before they are wiped out by erosion. It is noteworthy that the shift from progradation to retreat mainly occurs in deltas, one of the most suitable settings for early human occupation.

Credit: J. Kleinberg

Fig. 2.15 Standard dockside fish box containing bones of Pleistocene fauna trawled up by one trawler during one week of fishing in the North Sea. Industrial activity, bottom trawling, aggregate dredging, harbour and channel construction, cable and pipe-laying, and wind-farm construction, all disturb the sediments of the sea floor on a large scale, and have the potential to destroy prehistoric deposits. Bottom trawl nets in particular have retrieved large quantities of Pleistocene fauna bones from the North Sea.

Credit: J. O'Shaughnessy

Fig. 2.16 A drowned forest of tree stumps 7,500 years old was exposed on the coast of Galway as the result of storms in the winter of 2013-14.

While local studies provide detailed factual knowledge of rates of coastal destruction, this has not yet been systematized. Nor is it known whether the observed rates of destruction are accelerating, or stable. A system for classifying the causes and incidence of coastal erosion has been developed in the EUROSION project (see Chapter5). Climate change, changes of sea temperature and seabed vegetation, and changes in storminess or wave heights, may cause accelerated damage. Codes of practice exist in several countries to encourage industries to conduct pre-licensing surveys, and to report finds of a prehistoric nature.

2.3 Legal background

This working group cannot and does not aim to comment on the international legal implications of archaeological work on the continental shelf, or within the EEZs of coastal states, and the legal status of marine archaeology within European coastal states, or the extent of offshore jurisdiction. These are complex issues which can and should be examined by the relevant experts, and a guide to the problems is provided by Dromgoole (2013).

There is one question which does require clarification here, and that is whether international treaties and the UN Convention on the Law of the Sea (UNCLOS) itself define marine archaeology in such a way as to include or exclude sea bed prehistoric research. Most of the relevant international treaties were drafted before the archaeological advisers and legal teams were aware of the existence of prehistoric sites on the continental shelf. All the relevant international treaties do define their topic in such a way as to include seabed prehistoric research, sites and artefacts (Box 2.2).

BOX 2.2 Legal definitions and Continental Shelf Prehistoric Research

The following international and European treaties use phrases to define the subject of their reference which include seabed prehistoric sites and artefacts:

The United Nations Convention on the Law of the Sea defines archaeology in the sea using the following phrase (Article 303) ..."objects of archaeological and historical interest..."

The UNESCO Convention on the Underwater Cultural Heritage is based on the phrase "Underwater Cultural Heritage" Article 1.1(a) uses the phrase "... Objects of prehistoric character..." Article 9.1 states "... Protect underwater cultural heritage in the Exclusive Economic Zone and Continental Shelf.

The Valetta Convention 1992 Council of Europe, Article 1(1) refers to "...European collective memory and historical and scientific research..." Article 1.(3) (a) ... "whether situated on land or underwater..."

EC Strategic Environmental Assessment Directive 2001/42/EC..."significant effects on... (many items)... cultural heritage including architectural and archaeological heritage..."

Directive 2011/92/EU Environmental Impact Assessment, Article 3..."effects on the following factors... (c) material assets and the cultural heritage..."

At a scientific, aesthetic and pragmatic level, it is desirable that coastal states should locate, assess, and protect the prehistoric cultural heritage within their jurisdiction, but this hope carries many undefined implications regarding costs, responsibilities, liabilities, evaluation of sites, priorities, and potential conflicts with industry and other sea users. Nonetheless, continental shelf prehistoric archaeology is included by the phrases used in all principal policy documents at United Nations, UNESCO, and European levels, and these documents have been agreed and ratified in most cases by European states, with some notable exceptions.

Legislative measures to reassure investors that there will be no unforeseen delays in planning processes and infrastructure connections can give as much impetus to investment as financial support.

EC COM(2012) 494 final

The existing situation is encouraging in the sense that the proactive topic has been growing exponentially for several decades, but from a very low starting base in the late 1950's. The accelerating growth has come from scattered institutions, individuals, and some regional collaborative projects, especially in the Baltic Sea and the English Channel. SPLASHCOS has enabled, for the first time, a systematic evaluation of the subject, but this progress could be lost if new institutional structures or collaborative links are not established on a more permanent basis.

SUMMARY

Key research priorities

Advance high resolution ice edge models of Pleistocene ice caps through time, and accurate GIA.

Improve modelling of GIA, additional to local and regional tectonics, and computing accurate palaeo-coastlines.

Improve knowledge of early periglacial living styles (see Pitulko *et al.,* 2004). When did people first learn to prefer living near the ice by choice?

Mapping and technology

Apply advanced underwater imaging and monitoring technology to CSPR and use CSPR as a ground-truth field to boost further advances.

Develop multi-period mapping of palaeo-river valleys on the shelf.

Conduct strategic analysis on major gaps in site occurrence, both in time and location, related to key archaeological questions. What sites are lacking and needed most importantly?

Community and stakeholder organization

Develop collaborative trans-disciplinary (not only trans-sciences but trans-cultural and scientific researches) approaches to support new era in prehistoric archaeology.

Promote leadership within the existing successful but scattered community of researchers to spearhead the planning of coordinated projects, support training, and develop the case for funding at a European level.

Rapidly build on the progress of SPLASHCOS which provided a wealth of data and experience to justify and achieve strategic planning .

Export European experience for application, where relevant, in other parts of the world (Clovis and pre-Clovis migration of hunter-gatherers into the Americas and south-east Asia colonization).

Policy relevance

Embed the importance of the study and protection of cultural heritage in the policy context (Blue Growth, energy, raw materials, etc.) underpinning the rapid increase in commercial activities on continental shelf areas of the European seas.

3

Addressing challenges in research communities and collaboration structures

Image: E. Galili

In this chapter we review the institutional and social structure of the research community and what is being done by different groups. Also, we consider national policies and the viability and stability of the community, sources of research funds, and the risk of loss of momentum or collapse of regional efforts. We review the scale of activities in the archaeological and marine science sectors, some of the archaeological objectives, the distribution of sites found so far, the status of research groups and some of the difficulties encountered. The emphasis in this chapter is on the institutional structure of the work being done in relation to the long-term objectives.

Underwater research on prehistoric sites before SPLASHCOS, often pursued archaeological goals that were fragmented and conducted sometimes outside the academic and scientific mainstream, or by employees of museums, national parks, local volunteer groups and heritage organizations. A logical balance is now needed between the various types of institution with an interest or responsibility for prehistoric archaeological research. By the late 20th century the number of formally sponsored and well-managed projects was increasing. At the 3rd International Congress on Underwater Archaeology (IKUWA3, London, 2008), it was apparent that it was feasible to convene a session on the subject at a global level, which was followed by an edited multi-author book (Evans *et al.* 2014). The full range of papers presented at IKUWA3 is published by Henderson (2013).

During the SPLASHCOS COST Action, six training schools were run for early stage researchers with sea-going courses involving laboratory work and diving experience, such as the one at the site of the Atlit submerged Neolithic village. Image shows the archaeologists sorting finds after a dive.

3.1 Research communities

Analysis of the mailing lists and authors of papers during the 4 years of SPLASHCOS shows that the majority of participants were from university archaeology departments, followed by university geoscience departments, and then government marine research institutes, cultural heritage agencies, and private archaeological consulting companies. This shows the dynamic composition of the research community with an emphasis on academic research and the acquisition of knowledge, while the themes of cultural heritage management, and the development and application of advanced technology, were always present. The composition of the SPLASHCOS community by discipline and type of agency is shown in Fig 3.1.

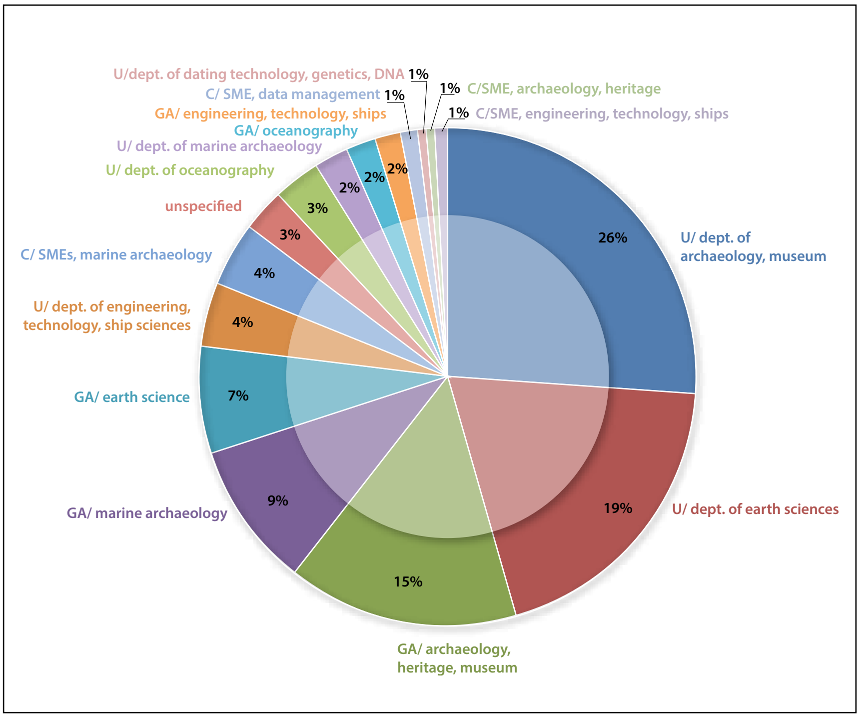


Fig. 3.1 Numbers of agencies, university departments and SMEs expressing interest in Continental Shelf Prehistoric Research in SPLASHCOS (Sample size =171). U=university; GA=government agency; C=commercial; SME=small-medium enterprise.

The format of the Joint Programming Initiatives (as JPIs) is ideally suited to assembling a multi-national group of participating agencies and institutes with the mixture of skills and resources needed, and should be investigated further as a way to advance Continental Shelf Prehistoric Research. The Joint Programming Initiative on Cultural Heritage gives very little mention of submerged landscape research, although considerable effort was given to getting it on the agenda. Apart from the JPI structure, it is difficult at present to see how a project proposal can be structured which crosses the border between the marine geosciences and the human-archaeological sciences which would have a chance of being funded. In fact it is difficult to see any research call at which such an application could be targeted or submitted. The mix of natural sciences and humanities is simply not catered for in current research funding programmes at European level.

3.2 Survey of cultural heritage agencies

Through collaboration with the European Archaeological Council (EAC), a questionnaire (Annex 5) was designed and circulated to EAC Member Departments and Agencies. The analysis of the survey (Annex 6) provides information about the activities and policies of national departments and agencies regarding the submerged prehistoric sites on the continental shelf within their jurisdiction.

Cultural heritage management is organized in different ways between the European nations, and the statutory obligations of departments with similar names may not be identical. The EAC Questionnaire produced 15 responses from 12 countries. Some countries replied at both the national and the regional or province level, where different regulatory and statutory regimes applied at different levels. While the numbers are rather small, they are just enough to see consistent and logical patterns. All respondents confirm that they carry responsibility for prehistoric remains found on the seabed as defined in the questionnaire. The replies also showed that in some countries different agencies are responsible for the foreshore, inland waters, the intertidal zone, the territorial sea, or further offshore.

United Nations Convention on the Law of the Sea	12
UNESCO Convention on Underwater Cultural Heritage	5
Valetta Convention 1992	12
Other conventions: European Landscape convention	2

Table 3.1 The extent to which the 12 countries that responded to the European Archaeological Council survey reported that they were signatories to four relevant international conventions.

The signing and ratification of UNCLOS is 100%, and this treaty does include Articles on marine archaeology. However, the ratification of the UNESCO Convention on Underwater Cultural Heritage is rather low. Regarding archaeology courses in higher education and the inclusion of Continental Shelf Prehistoric Research, the following countries reported that they run such courses: Belgium, Slovenia, Scotland, England, Norway, and the Netherlands. In terms of interdisciplinary collaboration, most respondents confirmed that they have had successful collaboration with the marine division of their National Geological Agency, their Hydrographic Office, and the national oceanographic institute. Most agencies expressed a willingness to extend such collaboration.

The recipients of the EAC questionnaire were asked to indicate whether they had research interests in a list of 18 topics related to Continental Shelf Prehistoric Research. The respondents were given an option “Other” at the end of the list, but this was not used. We can assume, therefore, that the proposed list covers most topics of interest to national cultural heritage departments and agencies. The SUBLAND WG did not conduct a similar survey of university archaeology departments. It is worth noting that, had this group been surveyed, some of the issues might have ranked differently and other topics might have emerged. It is to be expected that national agencies will put national priorities first, and that supra-national, cross-boundary, and European-scale topics will rank lower, or even exceed their area of competency. In addition, for these respondents, we can assume also that protection of sites, conservation and enforcement of the law are additional concerns or priorities.

In the prioritization of research topics (Table 3.2) the higher rankings comprise purely archaeological-cultural and environmental-landscape issues. It is notable that no department or agency identified evidence regarding hominin migration out of Africa as a priority area of interest. However, this is a major topic of research in palaeo-anthropology and human genetics and the landscapes of the migration paths 100,000 to 1 million years ago were substantially different from the continental limits today. Similarly, events before the LGM are given a lower priority, while they are of research interest in academic circles, and there is a steadily increasing number of known sites from this period. Hence, while the breadth of interest shown by the national cultural heritage departments and agencies is very significant, and makes a strong case for combining objectives and efforts at a European level, the range of important topics would be extended even further if university and pure research institutions were included. Given the widespread fascination with human evolution and the origins of our species, further knowledge of hominin migration patterns and lifestyles would also be of interest to a large non-specialist audience.

Table 3.2 Ranking of research topics identified by EAC Member Departments and agencies in responding to Question 18 in the Questionnaire. The score for each question is shown in the left column. Total number of responses = 15.

Score	Topic
10	Human response to rising/falling sea level during climate change
10	Origins of exploitation of marine resources and marine diet
9	Reconstruction of river channels and fresh-water drainage or karst on the submerged continental shelf
8	Demography and human response to climate change
7	Palaeo-environments and climate on the continental shelf at the Last Glacial Maximum
7	Earliest prehistoric occupation of islands presently separated from the mainland of Europe
7	Migration routes to and from the coast of your country
6	Origins of prehistoric seafaring
6	Reconstruction of vegetation and fauna of the continental shelf, providing an environment for hominins
6	Prehistoric non-lithic material culture which only survives in permanently waterlogged sediments
5	Palaeolithic re-population of recently deglaciated coastal zones
4	Study of population that has contributed to DNA of your region
4	Food, diet, population demographics, diseases, and life expectancy of Palaeolithic or Mesolithic populations
4	Changes in subsistence, such as the introduction of agriculture
3	Population centres as a refugium from nearby lands abandoned during glacial periods
3	Early hominin migrations and areas of occupation during previous glacial cycles
1	Domestication of animals and early farming and crops
0	Hominin and human migration or diffusion pathways from Africa into Europe

3.3 Management for optimal collaboration and research themes

It is the responsibility of those who wish to work on prehistoric sites at sea to make the case for funding to support their research goals. Ship time, if required, is very expensive (unless supplied free of charge through collaboration with industrial operators), but increasingly necessary for pursuing investigations in deeper water and outer areas of the continental shelf. The key, then, to the funding of research-driven underwater investigations must be the articulation of research questions that are of central importance to a wider understanding of prehistory – and that cannot be answered in any other way.

The subject has reached the stage where such complex research questions can be tackled, requiring large numbers of sites, or large quantities of data. But at the same time the search for new sites must continue, especially in areas where major gaps exist. It is possible to identify a number of core research topics that could be addressed with a larger dataset, that provide an intellectual incentive for the continued accumulation of new data, and that have the potential to transform our understanding of European prehistory and cultural heritage. The key fact that drives this intellectual agenda is the recognition that coastlines and their low-lying hinterlands have always been a major focus for human settlements and high population densities. This is true today, and for at least the past 6,000 years, and is likely to have been the case throughout the past 1 million years and more of European history, with generally more productive ecosystems, better water supplies and more attractive climatic conditions in coastal areas relative to their continental hinterlands, higher human population densities, greater diversity of material culture and subsistence activities, and wider opportunities for social interaction and mobility. When sea level stabilised about 6,000 years ago, we immediately see appearing on the coastlines that become visible at that time in many areas of Europe (and other parts of the world) large coastal settlements with dwelling structures, year-round residence, seafaring, fishing, sea-mammal hunting, shell mounds, food storage, burial grounds, megalithic structures, evidence of social ranking and a whole range of indicators that archaeologists typically associate with 'social complexity'. So dramatic is this evidence that archaeologists conventionally have regarded it as proof of a 'postglacial revolution' – a series of inventions and innovations that appeared from about 6,000 years ago onwards for the first time in human history.

It now seems more likely that this dramatic explosion of evidence is simply the product of increased visibility when sea level stopped rising, and that these innovations have a deeper history extending much further back in time by thousands and perhaps many tens of thousands of years, with the evidence now buried on the seabed. If that is so, it not only opens up the prospect of a much deeper and richer record of human history on the European continent, it also demands systematic exploration of the continental shelf to find the relevant evidence.

From this starting point, a number of research themes can be pursued, providing focal points for the ranking of topics by the EAC. These include:

(1) The attractions of coastal regions as unusually productive for plant and animal resources, with abundant water supplies, spring lines, coastal meadows and marshes, and sources of raw materials and intertidal molluscs along the shore edge. These are likely in some cases to have presented unique combinations of plant and animal resources with no equivalent analogue on modern coasts, and much richer than their contemporaneous hinterlands. Glimpses of these attractions are visible in caves on the present-day coastline with long archaeological sequences extending back to earlier short-lived episodes of high sea level, adjacent to steeply shelving offshore topography, or in material being eroded out of ancient coastal and riverine deposits by marine erosion on the modern coast. But the majority of relevant evidence and the key landscapes and palaeoenvironments in most areas are likely now to be submerged on the seabed.

(2) Closely allied to theme (1), the significance of these productive coastal regions as centres of population growth and pathways of population movement and dispersal into Europe during the earliest periods of the Palaeolithic era.

(3) The importance of offshore archipelagos as ‘nursery’ areas for early experiments in seafaring and maritime economies, and as stepping stones in coastwise expansion of early populations around the Mediterranean and into the periglacial and deglaciated regions in the North and Northwest of the continent.

(4) Closely allied to theme (3), the question of the earliest origins of experiments in sea crossings with simple rafts and boats, seal hunting, offshore fishing, and visitation of offshore islands that often offer rich concentrations of nesting birds and marine resources, or useful materials such as obsidian.

(5) The enormous potential impact of sea level change and resulting alterations in palaeogeography and environmental conditions on the social geography, demography, economic organization and cultural interaction of ancient populations.

(6) The deeper history of coastal sedentism, with year-round settlements, permanent dwellings, and other durable structures and monuments of stone or wood.

(7) The significance of coastal regions in providing fertile and cultivable soils and pastures for early farmers, and as pathways for the expansion of farming from the Near East into southern Europe, a process that was underway when sea levels were still considerably lower than the present.

(8) The over-riding importance of treating the present-day land surface and the submerged areas of the continental shelf as a seamless whole from the point of view of their prehistoric inhabitants, who are likely to have ranged widely over large territories untrammelled by present-day physical boundaries.

We expand on relevant examples below, further in Chapter 4, and summarize in Chapter 7.

The research community in Europe focused on Continental Shelf Prehistory Research is estimated at about 150 people. While this is a significant increase from 20 years ago, the numbers are still low. Since 25 countries are involved, the actual participation level per country ranges from 20 people down to 1 or 2, with an average of about 6. These small numbers include the entire professional range from professors or agency heads to students and volunteers, spread over several academic disciplines. Even when additional supporters are included - technicians, laboratory staff, and volunteer divers who help with projects by allocating part of their time and work - the numbers are still small. Hence, the community is below the level required to ensure good connections and adequate coverage of areas of interest at all geographical scales. With such small groups, the departure of one key person can cause collapse and abandonment of the subject in an institution or region.

SPLASHCOS has done much to improve the integration of this community in Europe. Major advances in ICT and data management practices have made it possible for individuals to connect efficiently to a community which is widely scattered. The development of collaborative regional groups, which has occurred independently and in parallel with SPLASHCOS, has also been an important part of the effort to create a community of experts. SINCOS[20] is a national-scale project, funded by the German Research Council, on archaeology and environmental change in the southern Baltic in the past 10,000 years. It has involved a wide range of researchers in archaeology, palaeoenvironments, numerical modelling, and geological and geomorphological processes (Harff and Lüth, 2007). SLAN (Submerged Landscape Archaeology Network), working with the Joint Irish Bathymetric Survey and with funding from INTERREG IIIA, is producing comprehensive bathymetric maps and landscape reconstructions around the Irish coastline (Quinn *et al.*, 2008), and IGCP (International Geoscience Programme) 521 on the 'Black Sea-Mediterranean Corridor over the Past 30ky: Sea Level Change and Human Adaptation' is a transnational network bringing together landscape and palaeoenvironmental reconstructions on the Black Sea shelf (Buynevich *et al.*, 2011). The North Sea Prehistory and Management Framework (NSPRMF[22]) is a research network of about 20 specialists from the UK and the Netherlands who are addressing similar issues (Peeters *et al.*, 2009).

Credit: N. Flemming

Fig. 3.2 Prehistoric wall of standing stones in a depth of 3m of water off the coast of Plitra, southern Lakonia, Greece.

[20]SINCOS: Sinking Coasts http://www2008.io-warnemuende.de/projects/sincos/

[21]http://submergedlandscapes.wordpress.com/

[22]http://www.english-heritage.org.uk/publications/ns-prehistory-research-manage-framework/

In spite of the multi-national structure and ideals of SPLASHCOS most of the projects which gained visibility, status, and funding by being associated with SPLASHCOS were conducted at the national or institute level. There were few multi-national or basin-scale projects, apart from the training schools. Collaboration between the southern Baltic States and between the UK and the Netherlands are exceptions. Also, the "Arch2Seas" project linking marine archaeology studies along all coasts of the southern North Sea and Channel involved Belgium, France, and the UK. This project was mostly concerned with shipwreck archaeology, but included a prehistoric component.

Addressing many of the big questions surrounding European prehistoric migration involves an interaction between large-scale hypotheses, models based on DNA, and ground-truthing archaeological data. The archaeological data tend to be sparse, and data from the sea floor are almost completely missing at present. Fig. 3.3 shows a model of possible post-LGM re-occupation of the western British Isles. The northward route along the Atlantic margin could only be confirmed on the ground by obtaining data from the French- Biscay continental shelf, or the western approaches to the English Channel.

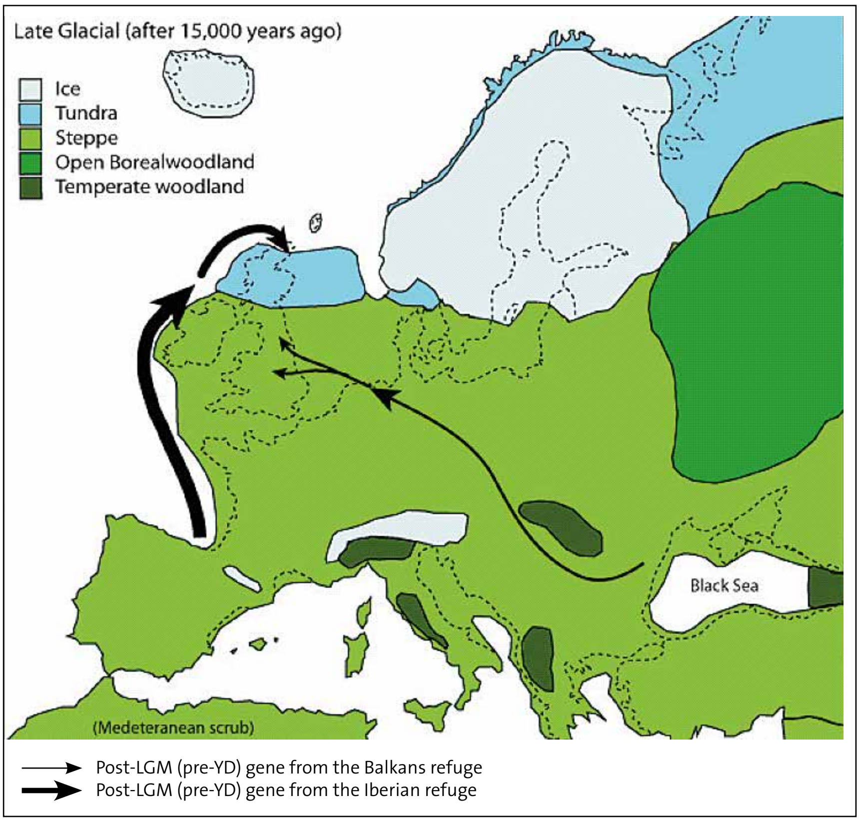


Fig. 3.3 Colonisation of the British isles after the LGM. A summary map of early re-colonisation gene flow into northern Europe and the British isles 15,000 to 13,000 years ago. The bulk came from the Iberian refugium, which contributed perhaps one third of maternal ancestors for the British Isles during this cool period. Most of northern Europe was grassland and rich in big game animals (Oppenheimer, 2006).

Understanding the role of the population on the floor of the North Sea since the LGM, let alone the earlier populations (Themes 1 and 2), requires collaboration of all the coastal states. Several sites pre-LGM have now been identified in the southern North Sea and fossil hominin footprints were recently reported from a beach on the coast of Norfolk (Ashton *et al.,* 2014) (Fig. 3.4). Similarly, the diffusion of agriculture from the Middle East through central Europe, along the northern shores of the Mediterranean, and into NW Europe (Theme 7) requires linking studies in many of the coastal states (Fig. 3.5; 3.6). Already studies between Haifa and Atlit in Israel have revealed several early Neolithic sites offshore, and the preservation of human bones and food remains reveals a complex diet which mixed produce from fishing and agriculture (Galili *et al.,* 2004).

The need for regional collaboration in the North Sea and English Channel is manifest. The NSPRMF has already been mentioned (Peeters *et al.,* 2009) and significant recent discoveries have been made in both Dutch and British coastal seas. The on-going excavations at Happisburgh, while not below low tide level, are flooded by high tide storms, and are continuously eroding. The sequence of papers on the East Anglian coasts and beaches (e.g. Parfitt *et al.,* 2010) culminated in the discovery of a pattern of hominin footprints dated to over 800,000 years old (Ashton *et al.,* 2014). Soon after the prints were photographed and measured, they were destroyed by the waves.

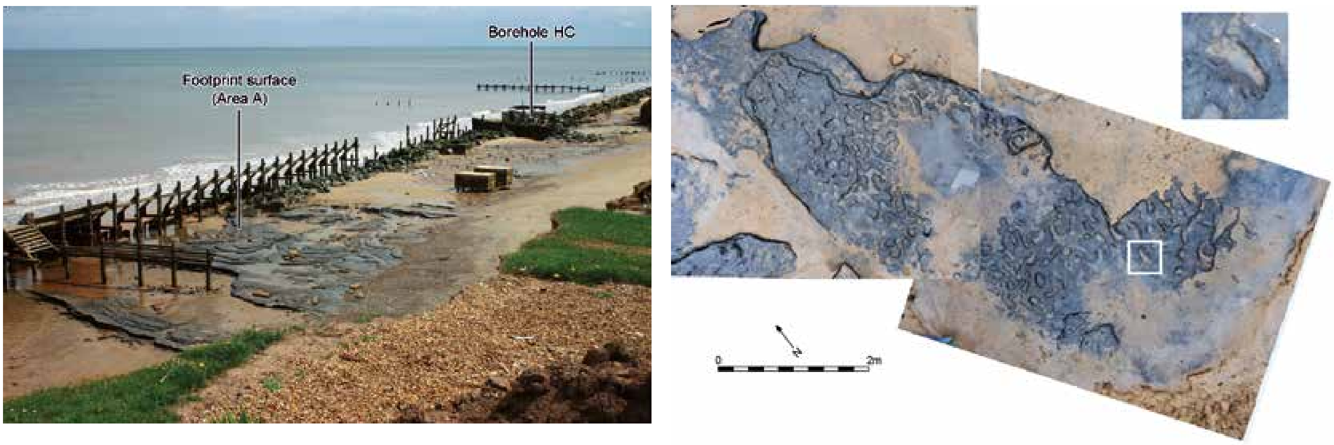


Fig. 3.4 In 2013 the storms in the North Sea eroded the beach at Happisburgh, and hominin footprints were discovered that were at least 800,000 years old in indurated mud layers from an ancient estuarine beach. (a) General view of the beach; (b) Close up of the footprints. (Ashton *et al.,* 2014)

Collaboration across the Channel and southern North Sea has already been promoted by the "Archaeological Atlas of the 2 Seas" project[23] , and further work of this kind is planned (Fenwick *et al.,* 2012).

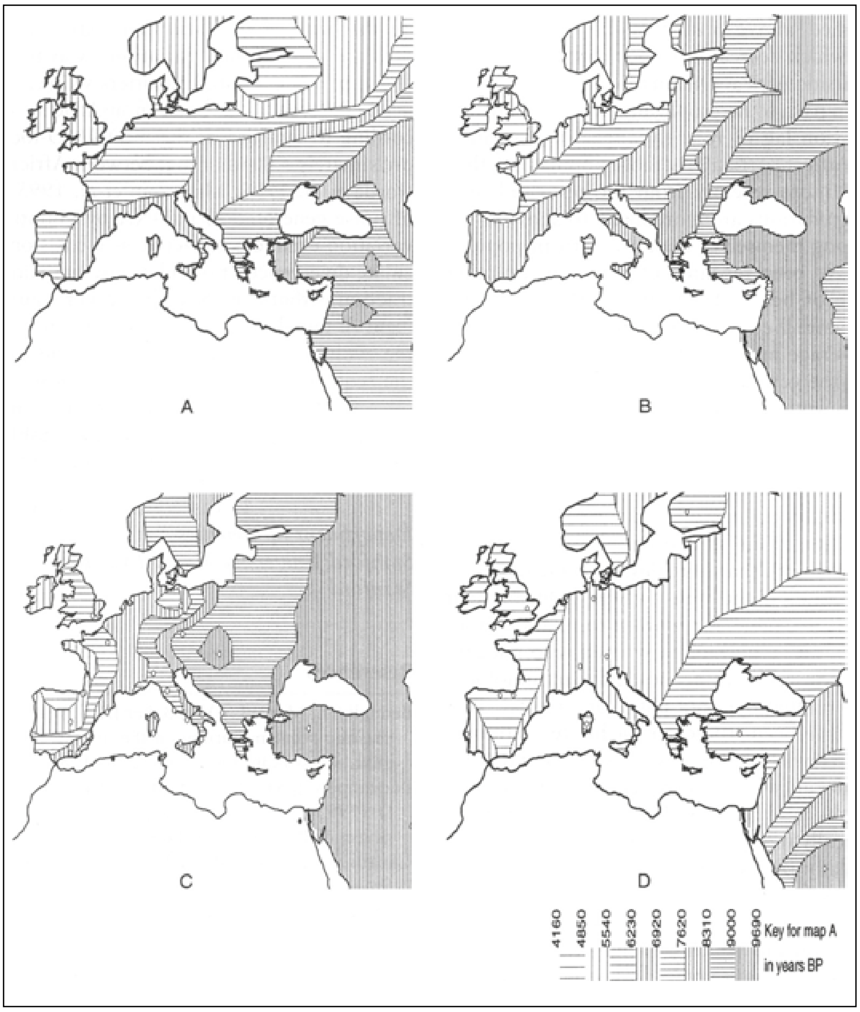


Fig. 3.5 An outline of Europe In sketch form with the progressive transition of th Neolithic revolution from about 10,000 to 6,000 years ago. This map can be seen as a proxy for the diffusion of agriculture from the Middle East to North-West Europe. (Cavalli-Sforza and Minch, 1997)

The multiple stages of hominin and modern human migrations into Europe out of Africa involved several periods of diffusion during the last 1.5 million years in different climate conditions and different levels of the sea (Theme 2). Conferences and regional workshops have been devoted to the interactions between human migrations, regional geological processes and changing sea level in the Mediterranean (e.g. CIESM, 2003) (Theme 5). The exposure of the wide continental shelf on the Levant coast, and the narrowing of the channels at Tunisia-Sicily and at Gibraltar, and the almost complete exposure of a terrestrial landscape interspersed with lakes in the Aegean, may have contributed to the complexity of the events.

[23]http://www.atlas2seas.eu/

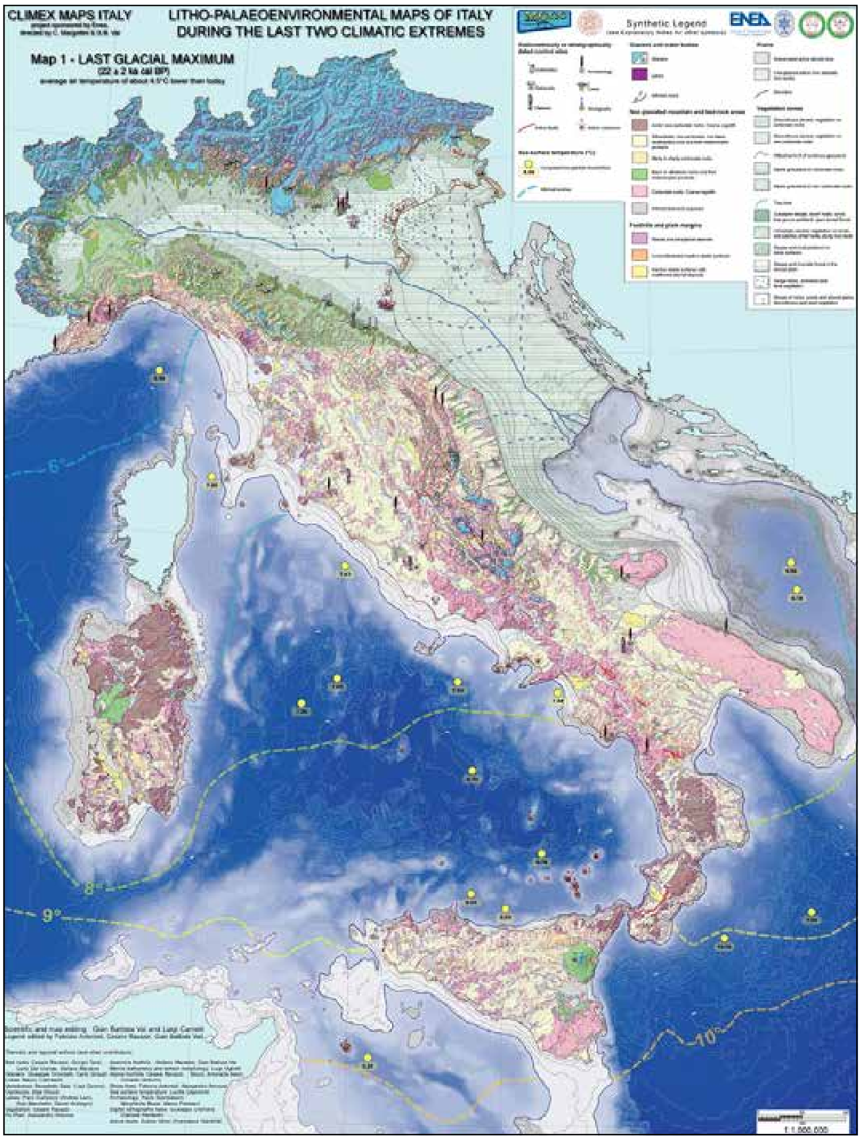


Fig. 3.6 The central Mediterranean at the LGM, showing the extensive flood plains of the Po River in the central Adriatic. The transition of Neolithic agricultural techniques along the North Mediterranean coast occurred when the sea level was still many tens of metres lower than at present, so that much of the change could have taken place on the present sea floor. This connection would have facilitated cultural connections between the land masses of Greece and Italy by a coastal route (Antonioli *et al.,* 2004).

At present, the Greek seas contain 3,500 islands and island clusters, the highest points of a submerged coastal shelf (Themes 1, 3 and 8). They were created by the latest rise of the sea-level. A good number of coastal prehistoric sites – settlements, burials/cemeteries, harbours, caves – lie partly in shallow waters; a handful of Stone and Bronze Age sites are fully submerged at greater depths or distances from the coast. The direct evidence of relative sea-level change in the late Quaternary (i.e. Upper Pleistocene and Holocene) has been a key theme in Aegean studies (Sordinas, 1983; Psychoyos, 1988; van Andel, 1989; Baika, 2008) (Theme 5). This area, in parallel with routes through or round the Black Sea basin, provides a variable bridge or barrier to communication between the Middle East and southern Europe.

a

Image: Google Earth

b

Photo: N. Efstratiou

c

Photo: J. Kleinberg

Fig.3.7a Aerial view of the small island of Aghios Petros in a bay on the south side of Kyria Panagia, Northern Sporadhes, Greece. The submerged prehistoric site is on the North West side of the island, sloping down below the sea.

Fig.3.7b The islet of Agios Petros in Northern Sporades and its 6th Millennium BC Neolithic settlement.

Fig.3.7c Over 100 bone fragments of sheep and goat recovered by divers from the submerged site at Aghios Petros in 1981. These fragments were embedded in the submerged terrestrial sediments within a 1m square quadrat.

The presence of Middle Pleistocene hominins and Early Pleistocene fauna on Lesvos (the latter also on many other islands of the eastern Aegean) offers indirect evidence about sea-level fluctuations in the early Quaternary. Both must have reached Lesvos from the Asian mainland via land bridges opened by low sea level stands and now re-submerged (Galanidou *et al.,* 2013). Lesvos is separated from the Asian coast by two sea straits. The northern one is a faulted trough more than 150m deep. The eastern is mostly shallow (under 50m) with an even seafloor. A glacial sea-level drop of only 50m would be enough to expose the eastern strait, connect the island with the Asian mainland and allow hominin and terrestrial animal migration. The Early Pleistocene fauna of Lesvos, found in seven fossiliferous sites, can be characterized as continental (Lyras and van der Geer, 2007), reflecting Lesvos' proximity to the mainland and the drowned land mass of the central Aegean Sea itself. Further discoveries on other Greek islands and on the sea floor between them can contribute an essential link in the early population movements into Europe.

The underwater Vamos Cave on the Drepano Cape in western Crete has yielded fossil remains of Pleistocene cervids and *Elephas chaniensis*, a species indigenous to Crete that probably went extinct at the end of the Upper Pleistocene. The only sources of Neanderthal fossils in Greece come from the wave zone of the Mani Peninsula. The inventory consists of: two crania extracted from the Apidima Cave, fourteen teeth, cranial and post-cranial fragments from the Kalamakia Cave on the rocky shore of Oitylo bay (not far from Apidima), and a molar from Lakonis I (Harvati *et al.,* 2003; 2010; 2013). The presence of earlier (at Apidima) and classic Neanderthals (at the caves of Kalamakia and Lakonis I) shows a well-established Neanderthal population in the area (*ibid*.). The present-day geography and topography of all three sites show the potential of further research in the now-submerged landmasses immediately fronting them. Understanding these would shed more light on their respective catchment zones that, to judge by the faunal and environmental remains of Lakonis I and Kalamakia (Elefanti *et al.,* 2008; Darlas and Mihailovic, 2008), once comprised grasslands, parklands, woodlands, lagoons and marshlands (Theme 1 and 4).

The Inner Ionian is a semi-closed sea bounded to the east by mainland Greece and to the west by Lefkas and Kephallonia and to the south by Ithaca. Surveys of the Inner Ionian Sea Archipelago brought to light an archaeological record spanning the Middle Palaeolithic to the Bronze Age. The survey results coupled with geological mapping and bathymetry suggest that the area is suited for studying both the submerged prehistoric heritage and landscapes, and early hominin seafaring (Galanidou, 2014) (Theme 4).

Middle Palaeolithic stone artefacts have been found on the Aegean shelf around the Sporades islands. Some of them may originate from caves now at depths of 40m off the shores of Kyra Panagia (Efstratiou, 2001), making the seabed around them yet another highly promising target of underwater research.

Off the same shores in the Sporades and in a cove in the vicinity of the caves is the drowned part of the EN settlement of the Agios Petros islet. Excavations on the remaining terrestrial part of the site by Theocharis in 1969-71 and Efstratiou in 1981 brought to light houses on the outskirts of a Neolithic village on a promontory. Occupation began at around 5,500BC and lasted for a millennium. The village was inhabited by no more than a few dozen people. From the ceramic finds and unique figurines, they were linked to the cultural tradition of Thessaly and the Cyclades, to those of Anatolia across the Aegean and to the Balkan Peninsula to the north. The site inventory includes domestic and fishing equipment – tools of bone and of knapped, polished and ground stone, weaving and fishing gear – and a faunal assemblage consisting of domesticates (sheep, goat and pig), fish, birds and ostracods. Two child burials in bedrock cuttings were also found. The submerged part of the village is at a depth of 10m immediately fronting the islet. The underwater exploration included mapping of the drowned site (Fig.3.8), controlled collection of archaeological finds and sampling for particle size analysis. The excavators concluded that Agios Petros preserves *in situ* deposits beneath the sea.

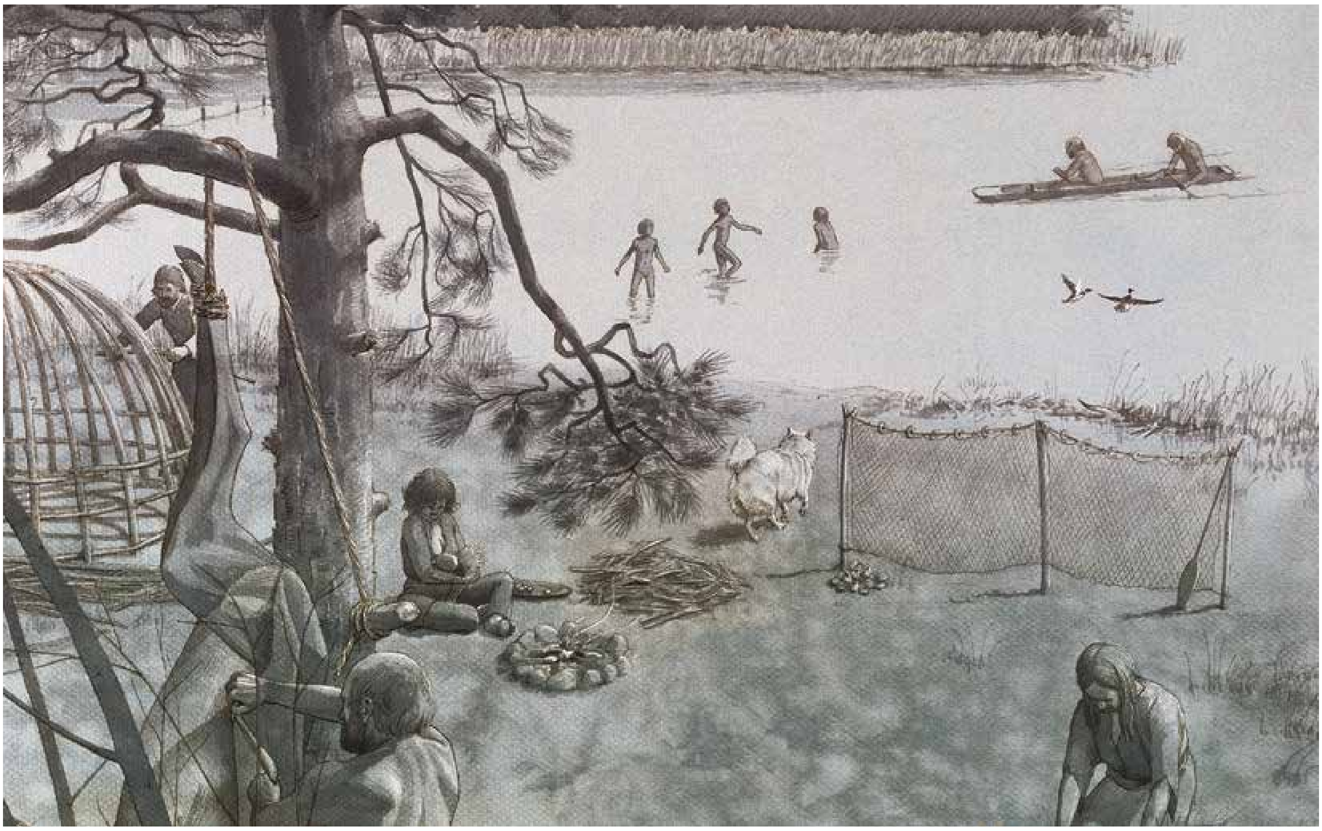
The prehistoric landscapes of the Aegean and the Ionian Seas are fortunately in areas protected by Natura 2000 and, although Natura 2000 only officially protects species and habitats, further work in them will require archaeologists joining forces with life scientists and local authorities who wish to promote this combination of cultural and natural heritage.

SUMMARY

Prehistoric archaeology of the sea floor does not stop or change its nature at modern national boundaries, and thus the subject is best studied in an integrated way at the scale of marine basins, considering both cultural and geomorphological processes from coast to coast. Continental Shelf Prehistoric Research has reached the stage where a number of key factors have been established, including: the survival of a representative sample of sites offshore, the survival of remnants of the Pleistocene terrestrial landscape; the ability of teams of researchers and divers to discover and work on the sites; and an infrastructure of communications and the means of collaboration. This creates the potential for cumulative, and indeed exponential, growth in the subject and its academic and cultural heritage benefits. Nevertheless, the network of groups and individual experts is still very sparse, and the volume of work needed is great, while the sites offshore are continuously threatened by erosion and industrial operations. Progress is limited by insufficient funding resulting from the low recognition and multidisciplinary nature of the subject. The identification of research themes and cultural heritage objectives provides a justification for further development of the field, increased training, and strengthening of regional and European collaboration to tackle large research ideas at a larger European scale.

Specific recommendations and conclusions include:

- Maintain the progress on integrating the research community through continuation of the SPLASHCOS website and e-mail list and the Deukalion Planning Group.
- Strengthen links between research community, cultural heritage agencies, and public agencies with competency for marine spatial planning.
- Ensure optimum interactions between the various relevant institutional groups and structures, including university departments, volunteer groups, heritage agencies, and museums, all with legitimate roles to perform in Continental Shelf Prehistoric Research.
- The research objectives defined by the EAC Questionnaire describe a strong case for Continental Shelf Prehistoric Research, emphasising climate change, sea level change, and human responses.
- The research objectives can be grouped into major intellectual themes related to the early stages of complex human social structures before the development of agriculture, and mechanisms of migration and cultural diffusion.
- Integrated Continental Shelf Prehistoric Research needs to demonstrate the accuracy of models of human migrations and diffusion by ground-truthing them according to DNA and human genetics.
- The Joint Programming Initiatives offer the possibility for funding multisciplinary multinational projects that could address future research at the European level.



An artist's view of a typical Mesolithic costal settlement at the Baltic Sea.

4

Tackling the problems of preservation, support and training

Credit: J. Goldhammer, NIhK Wilhelmshaven

Continental Shelf Prehistoric Research is a young and emerging discipline, but it has already greatly expanded our knowledge of the lifestyles, and environmental conditions of prehistoric peoples. In many cases the excellent preservation conditions in waterlogged sediments of objects in daily use - tools and constructions made from bone, wood or other organic materials - have already offered a completely new insight into prehistoric life. These remains buried and conserved on the European seafloor, must be regarded as an immensely valuable archive of human history. An increase in Continental Shelf Prehistoric Research in future will not only widen our knowledge about submerged landscapes and their use and habitation, but also about the human adaption in the past to climate change, to rapidly rising sea levels and generally to a changing environment and habitat.

Image: S. Hartz, Archaeological State Museum, Schleswig

Fig. 4.1 Mesolithic settlement remains of organic material have survived 7,000 years in the waterlogged sediments of the Baltic Waters near Neustadt (Germany).

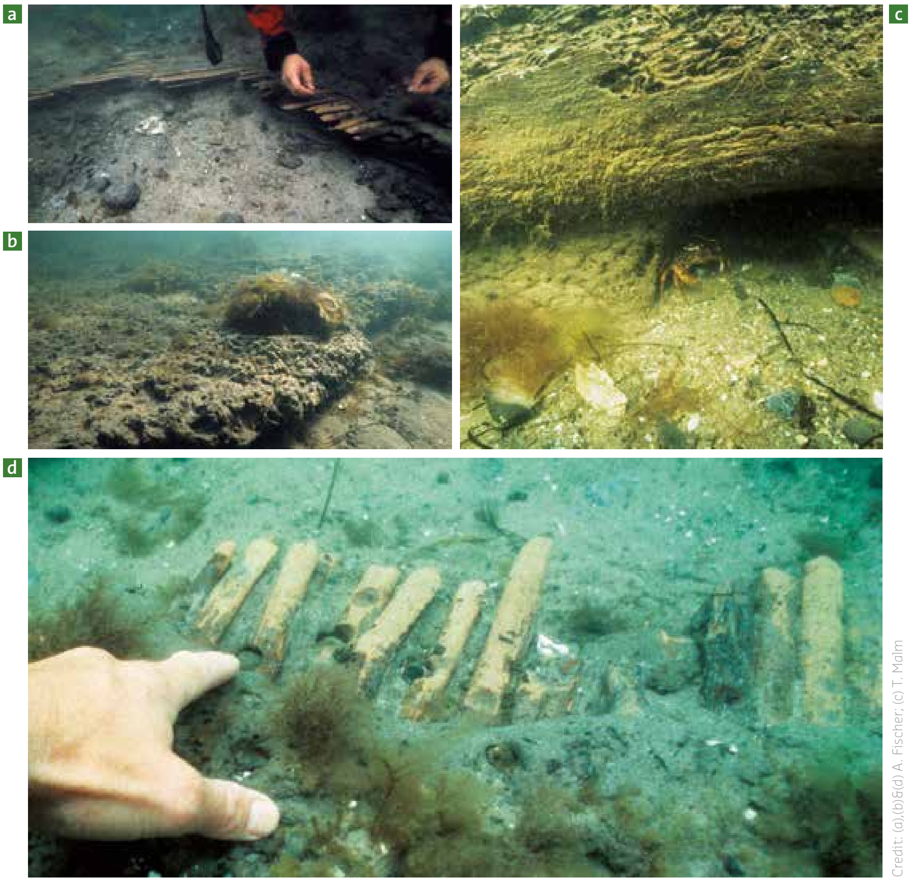
As shown in the previous chapters, investigations of submerged prehistoric landscapes and sites have increased significantly and have produced new knowledge, especially during the last 30 years. At present, this is largely based on the activities of a small community of researchers from various disciplines, indicating that interdisciplinary and international cooperation will be key to the establishment of a sustainable scientific network that is able to broaden and intensify the research on the submerged part of European prehistory. Within this research, attention must be focused on successful detection and mapping of archaeological sites from all submerged prehistoric periods and a detailed reconstruction of the sea-level and landscape development in all parts of the continental shelf. Because so many offshore sites have been lost already, each new discovery provides a unique window into the previously complex pattern of land use.

Action is needed now, because the consistency of these archives is threatened by various factors – partly natural and partly man-made, so that it will certainly not be possible in every case to conserve their remains on site and *in situ* for future generations. Knowledge will be irretrievably lost.

A research team verifies predictive modelling in the German Wadden Sea.

4.1 Threats to Continental Shelf Prehistoric Research

Climate changes affect chemical, physical, geological and biological conditions from the substrate to the waters covering the continental shelf. Offshore economic activities such as fisheries, oil and gas extraction, construction of windfarms and energy pipelines, will continue to expand into new areas. Offshore dredging leads to large scale destruction and relocation of sediments of the active zone and changes the local systems of currents and sediment transport. Although in many cases these new artificial landscapes become habitats to species that recover, or to new migrating aquatic communities after a short while, the previous landscape and historic archives of prehistoric settlements are lost forever.



Credit: (a),(b)&(d) A. Fischer, (c) T. Malm

Fig. 4.2 Seafloor erosion and destruction by biological factors, documented in the Danish part of the Baltic Sea. (a) Erosion of a Neolithic wattle construction (b) Clay gyttja exposed by erosion and pitted from an attack of piddocks. (c) Mesolithic oak trunk destroyed by shipworms, (d) Hazel rods from a prehistoric wattle, penetrated by piddocks (Fischer, 2011).

Changes in environments and the effect on archaeological site preservation

Marine ecosystems are changing as a result of climate change and human pressures. The extent of the changes taking place varies in different locations and latitudes but often the changing environmental conditions lead, in turn, to a changing biodiversity, with new species assemblages becoming predominant. Such biotic changes can alter the preservation conditions of archaeological remains. An example is the decline of eelgrass vegetation in the western Baltic (Fischer, 2011). These plants usually grow in shallow waters near the coast and can reach a height of more than a metre. They significantly reduce currents and water turbulence and with their systems of roots and belowground stems they stabilize the substrate they are covering. Eelgrass meadows are effectively able to prevent the erosion of the underlying sediments. Observations in Denmark and Germany have recorded a progressive decline in the extent and density of the eelgrass vegetation. This is leading to augmented erosion of the shallow part of the seabed and, in turn, to the destruction of numerous archaeological sites. Erosion often leads to the exposure of prehistoric artefacts, tools and constructions which have been embedded and conserved in waterlogged layers for thousands of years. Now they may easily be attacked and destroyed in a few years by migrating shipworms, piddocks, and other species. Similar accelerating processes of erosion and devastation of the shallow part of the sea floor have been reported from several other parts of European waters and may even be considered a global phenomenon. Even though a rudimentary photographic documentation or video-recording of the visible prehistoric fire-places, graves and other man-made remains is often possible, a real scientific investigation of the rapidly eroding sources is not. Covering the threatened areas with geotextiles or sand can only be done in a few exceptional cases. So developing new intelligent methods for the protection of eroding sites and landscapes on the sea-floor is an important challenge for the future, and this is under development in the frame of the EU FP7 SASMAP Project (Gregory, 2012).

Fig. 4.3 Dredger in action off the English coast (Bicket, 2011).

Expansion in offshore activities

Until the end of 2nd World War mankind considered the marine waters primarily as fishing grounds or as zones for maritime transport. Today, shelf seas which are mostly within the exclusive economic zones (EEZ) prescribed by the United Nations Convention on the Law of the Sea, are used by many countries for oil and gas extraction and especially within the last two decades for the installation of large scale wind farms for the production of renewable energy. Numerous supply and service lines as well as pipelines have been constructed to connect offshore industrial platforms to the onshore transport and consumption system. These offshore structures not only cause disruption of the seabed but in many cases are also leading to changes in currents, erosion and sedimentation processes in the active area and its surroundings. As a side effect, prehistoric remains may be disturbed, exposed to erosion or even destroyed.

During the last five decades, large-scale dredging and flushing of gravel and sand have become an important economic activity. The deposition of offshore extracted material as a buffer against the erosion of beaches and sea cliffs caused by sea level rise is used as a coastal protection measure in many European countries. The dredging of the required sand and gravel is often done in the vicinity of the areas to be protected, resulting in the rearrangement of sediments on an enormous scale. If the dredging is conducted in the proximity of a prehistoric site, it will not only affect or disturb this archive but also lead to a relocation of the archaeological material to a new location, thus forming a secondary find-spot at a place where possibly no human settlement had ever existed.

Although the economic significance of European fisheries has declined in recent decades, fishing is still conducted across all European sea areas. Bottom trawls or dragnets have been in use since the beginning of the 20th century, mainly in the North Sea and the Atlantic. Beam trawls have a particularly strong effect on the archaeological remains on the seafloor, because they stir up the sediment at the sea bottom to a considerable depth. This leads not only to ecological disruption, but also to the relocation of sediments and archaeological artefacts. Despite the 2004 UN General Assembly recommendation that countries should consider at least temporary bans on high seas bottom trawling, it is still in practice today and looks set to continue for some time to come.

Gaps in human capacity building

The young discipline of Continental Shelf Prehistoric Research is shaped by experts from many different scientific disciplines including geologists, geophysicists, archaeologists and heritage managers. There is a marked shortage of professionally trained personnel in this field. Information on university programmes and courses in submerged prehistory is difficult to obtain, with rare courses on marine archaeology. Furthermore, it is difficult to obtain good text-books or monographs which analyse the subject at the right level for students. Some standard archaeology texts are dismissive, or say that prehistoric sites cannot survive inundation. There is an urgent need to improve this unsatisfactory educational situation. An example of positive action in this contect is course material designed to educate archaeologists in marine geotechnical methods (English Heritage, 2014).

4.2 Turning threats into opportunities

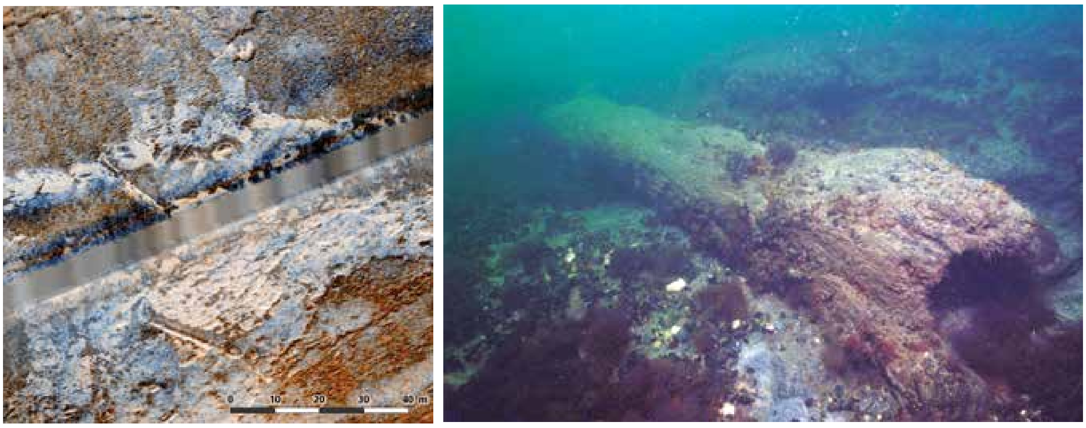
Research on climate change, sea-level development and human adaption

During the last two decades, enormous budgets have been spent worldwide to identify the driving forces of climate change and to create models that can allow us to preview future developments and to prepare measures in response to the unavoidable consequences. On the other hand, so far only a few funding bodies have supported research on the comparable developments our prehistoric ancestors had to face thousands of years ago. Applications for financial support or grants for the investigation of submerged prehistoric landscapes at present are almost only possible at the regional or national level. Studying the strategies that prehistoric communities used in their day cannot be directly adapted in our industrial world of the 21st century, but the scientific data that research may produce on the magnitude and consequences of sea level change impacting the environments and landscapes in the past are certainly of great interest for the verification of predictive models about expected future developments.

This can be impressively demonstrated by the example of the transdisciplinary Sinking Coasts (SINCOS) Project that was funded for almost one decade by the German Research Foundation (DFG). The main focus of the project was the reconstruction of the Littorina Transgression for the southwestern part of the Baltic Sea during its highest intensity between 8,000 and 4,000 years BC and the consequences this development had for climate, vegetation and landscape (Harff and Lüth, 2007). In addition, it aimed to find the extent to which the sea-level rise shaped the life of the hunter-gatherer and fisher communities along the south-western Baltic coast in that period and in what way they adapted their economic and social system to their changing environment (Jöns *et al.,* 2007; Jöns, 2011).

These investigations showed clearly that people living in the maritime zone between the Oder estuary and the Oldenburg Rift were facing a continuous shore displacement and a coastal decline during the Littorina Transgression, forcing them to move their settlements successively to protect them from inundation. Because the intensity of the isostatic rebound surrounding the postglacial uplift of northern Scandinavia differs regionally, the coasts of the Bay of Mecklenburg in the western part of the investigated area were affected by this phenomenon to a much larger extent than those of the Arkona Basin and the Pomeranian Bay in the east. The research results suggest that the remains of human settlement positioned on the shore can indicate the relative sea level at their particular period of utilization. A systematic survey based on geophysical measurements (side scan sonar and seismic) led to the discovery of numerous submerged archaeological sites and landscape remains such as tree trunks, peat-blocks and riverbeds of late glacial natural drainage systems in both research areas. Some of these sites offer exceptional conditions for the preservation of organic material, so that artefacts as well as tools and multifaceted settlement refuse in large quantities could be recovered during surveys and excavations.

Credit: F. Tauber/ Institute for Baltic Research Warnemünde



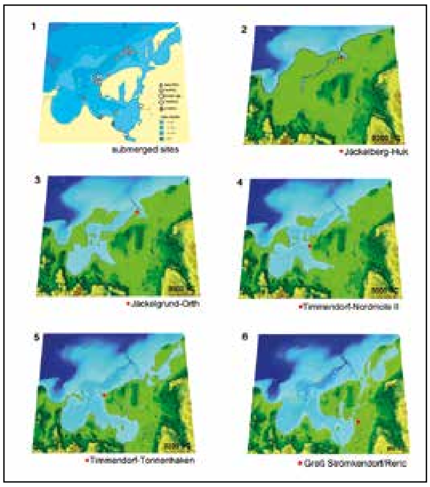
Credit: H. Lübke/Archaeological State Museum, Schwerin

Fig. 4.4 A tree trunk *in situ* on the sea floor at the Jäckelberg, Wismar Bight (Germany) (Tauber, 2007). (Left) Detected with side scan sonar (Right) Documented with the help of a ROV

Field work was restricted to sites from the Late Mesolithic until Late Neolithic period between 6,000 and 2,000 cal.BC, because their remains should reflect the human reaction to the Littorina Transgression in a specific manner. In the Bay of Wismar, a large number of well-preserved submerged - originally coastal - sites were located, surveyed, and in some cases, partly excavated. The material from these sites forms the basis for a detailed reconstruction of the chronological development from the Late Mesolithic to the Early Neolithic and the settlement history for the period from 6,000 until 4,000 cal. BC. It also allows for a reconstruction of the intrusion of marine waters during the Littorina Transgression and the subsequent creation of the Bay of Wismar.

When considering the suitability of archaeological sites as sea-level index points, particular attention has been paid to a group of more than twenty submerged settlements, today located at the bottom of the Wismar Bight at depths between 2.5m and 11m below present sea level. Most of these were discovered during side scan and Hyball surveys and, at a later stage, partly excavated underwater by divers. As well as seeking answers to several questions about the settlement pattern and chronology of the respective sites, a further aim has been to gather data about ancient coastlines and the dynamics of the rise in sea levels. The most important sites are briefly presented here.

Of special importance is the Jäckelberg-Huk site, located on the edge of the Jäckelberg at a depth of 8.5m below present sea level. Radiocarbon analyses indicate that the site existed in the period between 6,400 and 6,000 cal.BC. So far it is one of the oldest known submarine sites in the Wismar Bight. The fish remains found at the site indicate a freshwater environment; the settlement must, therefore, have been situated in immediate proximity to a fresh-water lake. Only a few kilometres south of the Jäckelberg, the Timmendorf-Nordmole II site was found.



Credit: 1: H. Lübke, Schleswig; 2: H. Jöns; 3-6: M. Meyer, Warnemünde.

Fig. 4.5 Submerged archaeological sites and Scenarios of different stages of the Wismar Bight (Germany) from the late 7th millennium BC to the 1st millennium AD (Jöns, 2011). 1. Distribution of submerged sites, 2-6 Scenarios.

Here, parts of a fishing fence were excavated at a depth of 5m below present sea level, which had blocked the end of a small brook. The preservation conditions for organic material on the site were excellent; wooden artefacts such as several leister prongs and parts of a fish trap were recovered. Analysis of the find material and a series of radiocarbon dates place the site in the period between 5,100 and 4,800 cal. BC (Hartz and Lübke, 2006). The neighbouring site, Timmendorf-Nordmole I, was investigated at a depth of 2.5m - 3.5 m below present sea level. Radiocarbon dating places the site in the period between 4,400 and 4,100 cal.BC. A special highlight of this site was the discovery of a pit that was covered with a number of long logs and poles, indicating that the pit had originally been covered over. From this pit a truncated blade with a well-preserved crosshandle made of hazel wood and lime-based binding was recovered (Lübke, 2005). The sequence of Stone Age sites around the island of Poel is completed by the site Timmendorf-Tonnenhaken, where settlement remains were identified in a depth of 2 m below present sea level (Lübke, 2002). The site is situated on a former peninsula and has a cultural layer with well-preserved artefacts made of stone, bone and antler. Potsherds prove that it was occupied by people of the Neolithic Funnel Beaker culture in the period between 3,200 and 2,700 cal.BC. That the transgression did not stop in the area of the Wismar Bay with the end of the Littorina transgression can not only be seen by recent measurements of the coastline but also by the remains of a trading centre from the early medieval period, that were investigated near Groß Strömkendorf on the shore of the Wismar Bight. This site is located only a few kilometres south-east of the above-mentioned Mesolithic and Neolithic sites of the coast of Poel island.

The site was occupied from the early 8th until the beginning of the 9th century AD and is presumably identical to the *"Emporium Reric"*[24] mentioned in the Frankish annals (Schmölcke and Jöns, 2013). The site's waterfront is of special interest in the discussion of shore displacement in the area of the Wismar Bight. Geological and geophysical investigations have proved that the harbour was located in a long stretched-out bay that had been washed out by meltwater in the deglaciation phase and that in the early medieval period formed an ideal natural harbour. Due to the rising sea level the shoreline of the ancient bay is displaced now by about 80m towards the coast so that the former waterfront area and harbour basin are completely submerged. This indicates that the sea level in the 8th Century AD was 80 to 100cm lower than at present.

Within the SINCOS project the archaeological data reported above were used together with geological and palynological data for the calculation of a new sea-level curve for the Wismar bay (Lampe *et al.,* 2005). When these data are plotted on the curve, there is a high degree of concordance between the different sources, which emphasizes the significance of archaeology-based data from sites that were occupied for only a short time. Based on these data and the IPCC suggestions about the future development of the global sea level, a prognostic coast line scenario was developed for the Wismar Bay that may demonstrate possible implications for the future.

[24] *"Emporium Reric"* is the presumed Latin name for the port in a medieval text.

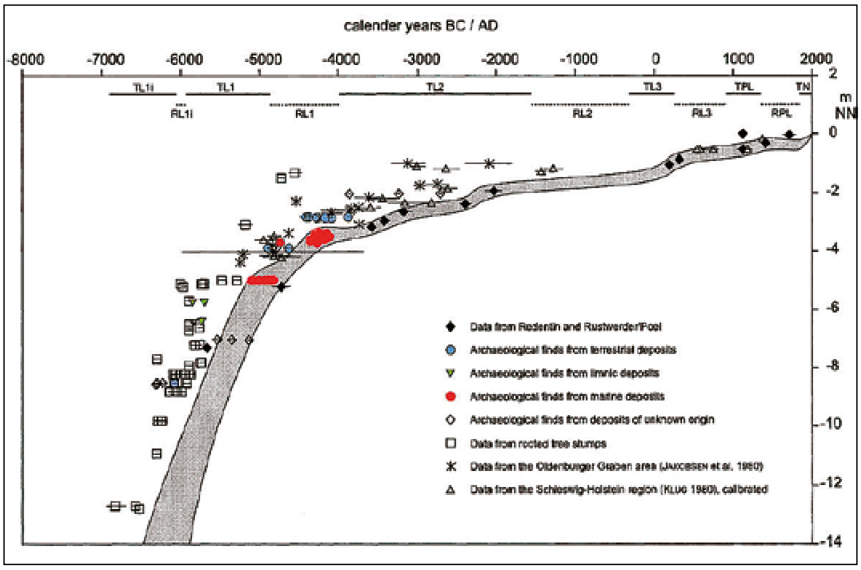


Fig. 4.6 Relative sea-level curve for the Wismar Bight as reflected by AMS-14C data from peats, rooted tree trunks, archaeological finds and published data.
T = transgression,
R = regression (after Lampe *et al.,* 2005).

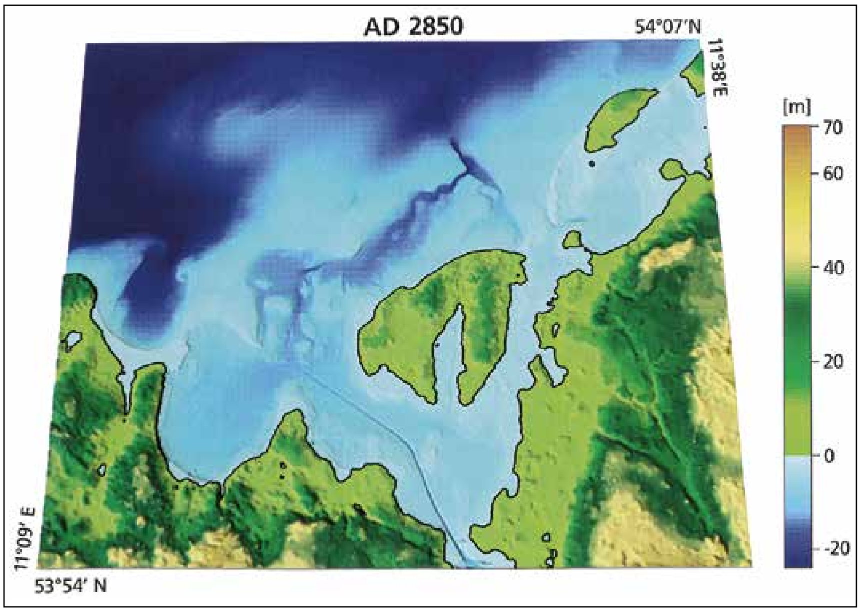


Fig. 4.7 Wismar Bight. Prognostic DEM2850 (AD 2850) for the Baltic Sea based on IPCC Sea-Level Scenario 4x CO_2 in the next 120 years – then constant (after Meyer and Harff, 2007)

Research on preservation, safeguarding and conservation

The investigations described above, whether motivated by research or cultural heritage management, show impressively that the development of commonly accepted international standards and best practice guidelines for organizing research and preservation of submerged prehistoric landscapes and archaeological sites must be an important goal. There have already been attempts that need further development. Most of them were products of two EU-funded projects, SASMAP and MACHU. Based on the Valetta treaty (1992) and on UNESCO's Convention for the Protection of the Underwater Cultural Heritage (2001), their goals were to ensure that submerged sites should, where possible, be protected *in situ* and, only investigated with non-intrusive methods to document and study them. Although these projects were primarily dealing with ship-wrecks, their results concerning the safeguarding and long-term preservation of waterlogged wood, the threats to wood by ship worms, bacteria, fungi, etc., and measures to protect it, are also of high value for submerged prehistoric landscape research. In particular, the MoSS project[25] (Monitoring, safeguarding and visualization of North European shipwreck sites), MACHU[26] (Managing under water cultural heritage), the project "Wreck Protect[27]", and the WoodCultHer[28] project (Wood Science for Conservation of Cultural Heritage), with their combined analytic and experimental approach have produced a large amount of information, which is already partly integrated into some national conservation strategies. In addition, the SASMAP project[29] uses a broad scientific approach to develop new technologies and best practices to locate, assess and manage Europe's underwater cultural heritage effectively.

Credit: E. Galili

Fig. 4.8 In the excellent visibility of the eastern Mediterranean waters of Israel prehistoric remains can easily be identified. The image shows a 9,000 years-old megalithic structure at Atlit-Yam, Israel.

At present, climate change and commercial activities are threatening the submerged prehistoric landscapes and archives of drowned settlements. Although many methods for the identification, documentation and scientific investigation of these sites have been developed during recent decades, and much new information could be gathered, we are still far from a systematic open accessibility and management of the diverse sources of information which are of extraordinary importance for the reconstruction of our prehistory. Most of the thousands of sites, known and investigated to date were situated in shallow waters of up to 10 m depth in areas with excellent visibility, dating to the Mesolithic or Neolithic period. Compared to that, our knowledge about sites and landscapes from deeper waters, in poor visibility conditions and with strong currents and sediment transport, is rather limited. Following the assumption that the deeper a site is below sea level, the older it is, it is no surprise that submerged late Palaeolithic sites that can be found in water depths of between 25 to 50m are known in much smaller numbers. To date, discovery of these sites has mostly happened in the frame of interdisciplinary research projects. This indicates, not only that these earlier sites and landscapes are still preserved on the seafloor, but also that more and broader based interdisciplinary cooperation is needed to extend the research and to locate and investigate them.

[25] http://www.mossproject.com/
[26] http://www.machuproject.eu/
[27] http://wreckprotect.eu
[28] http://www.cost.eu/domains_actions/mpns/Actions/IE0601
[29] Development of Tools and Techniques to Survey, Assess, Stabilise, Monitor and Preserve Underwater Archaeological Sites. http://sasmap.eu/

Research and collaboration with industry

The implementation of the cost-by-cause principle as defined in the Valetta Treaty in most European countries has generally produced a basis for funding investigations to study those prehistoric sites and landscapes that are affected directly by construction works. When the necessary archaeological investigations are integrated into the planning process of the construction project from the beginning, an effective cooperation between industry and science can be achieved. Overly restrictive regulations are perceived as burdensome by industry and are difficult to enforce. If the research community works with industry, and if voluntary codes of practice can be developed, those engaged in offshore activities will report their finds more willingly, and costs of enforcement and restrictions will be reduced. These can then be backed up with more limited but stronger regulations.

SPLASHCOS set out to build links with those industries that routinely disturb or lift seabed sediments and that conduct acoustic surveys of the seabed. EMB WG SUBLAND has since also engaged with the European Dredging Association (EuDA) to discuss common interests. A highly successful joint conference with marine industries was held in Esbjerg, Denmark, in March 2013. The Esbjerg meeting brought together participants from academia and industry, along with relevant stakeholders, with the goal of assessing the role and impact of commercial activities on the management of submerged landscapes. The workshop included intensive discussion on the relations with the fishing industry, which laid out how different fishing methods could profitably be deployed to enhance the knowledge base of prehistoric landscapes.

The technology needed for finding small objects on the seafloor may represent a good test field for military prototypes designed for the detection of small objects and could provide “real” ground-truthing for methods and instruments. There is a continuous interaction between those industries and services which require accurate offshore data and the needs of the Continental Shelf Prehistoric Research. The detail needed for archaeological research on continental shelves may boost studies, technologies and methods aimed at reconstructing micro-climate, change in vegetation, coastline positions and associated deposits that are of interest for other purposes (climate change, environmental evolution, detailed habitat mapping, prospection for relict sand and gravel). In this respect, it correlates well with the increasing interest at European level regarding integration of marine environmental data under the Marine Strategy Framework Directive (MSFD), and EU policy developments in Maritime Spatial Planning (MSP) and Integrated Coastal Zone Management (ICZM).

An example of research-industry collaboration is the large scale archaeological and palaeo-environmental investigations that were done recently during construction works for the enlargement of the port of Rotterdam in the Netherlands. Here large scale archaeological investigation took place on the seabed prior to the construction works at a location known as “Maasvlakte 2[30] ”. Artefacts up to 30,000 years old were retrieved including teeth, tusks, vertebrae, bones of mammoths, hyenas and many other animal species, together with prehistoric artefacts, indicating that the area was part of the habitat of Palaeolithic hunter communities. Based on an agreement between the Port of Rotterdam Authority, the contractor for the Maasvlakte Expansion Project and the State Agency for Cultural Heritage, Ministry of Education, Culture and Science of the Netherlands, it was ensured that, on the one

[30] https://www.maasvlakte2.com/kennisbank/archaeology.pdf

hand the archaeological finds were systematically salvaged, carefully handled and scientifically analysed and on the other hand that the progress of the construction process could stay on track as scheduled. The archaeological project was completely funded by the Port of Rotterdam Authority. The construction works led, not only to the discovery of outstanding cultural remains, but also to much detailed new data about the submerged prehistory of the southern North Sea (van Ginkel, Reumer and van der Valk, 2014). The project has also led to a range of publications including Weerts *et al.* (2012), Borst *et al.* (2014) and Moree and Sier (2014). A comprehensive book in English will be published in the near future.

Fig. 4.9 The good cooperation between contractors and prehistoric researchers is documented by a book presenting the new results of the Maasvlakte project.

Offshore operational activities such as cable and pipeline projects have in several cases been also carried out in conjunction with international archaeological projects. Even if the width of the pipe or cable tracks is limited to a few metres, they often penetrate the seafloor along-track for hundreds of kilometres, while the cable-laying operations require anchors that spread for many tens of metres on each side. This work may change the rate of sedimentation as well as other environmental conditions that could, in turn, affect the preservation of submerged sites or even destroy them. For this kind of project, the main focus in the past was given to historical shipwrecks. However, today the enormous scientific significance of submerged prehistoric landscapes and sites is broadly accepted. An example is the Nord Stream pipeline that established a new gas supply route from Russia through the Baltic Sea to Western Europe. Starting in the Portovaya Bay near Vyborg in north-western Russia and ending in Lubmin near Greifswald in north-eastern Germany, the pipeline runs for more than 1,200km through the exclusive economic zones (EEZs) of Russia, Finland, Sweden, Denmark and Germany. In Russia, Denmark and Germany the pipeline also passes through the national territorial waters. The responsible national archaeological authorities of these countries worked together during the entire planning and construction process, so that historical remains – shipwrecks as well as submerged landscape remains – were respected at all stages. In addition, the necessary scientific investigations were completely financed from the project's budget.

In an early stage of the project a reconnaissance survey was carried out to facilitate the selection of the best pipeline route based on information on geological and anthropogenic features. A 2km-wide corridor was surveyed with a full range of geophysical techniques including side scan sonar, multibeam echosounder and magnetometer. The survey aimed to document the seabed topography, to model the bathymetry in a 2x2m grid and to identify active geomorphological processes. In addition, the mapping included potential geological features, environmental constraints, munitions and debris but also historic ship-wrecks and remains of submerged prehistoric landscapes. The survey data were carefully analyzed by skilled experts at research institutes or universities; identified sites and features were finally visually inspected by ROVs and, where appropriate, further investigated and sampled by teams of scientific divers.

Of special interest for research on submerged prehistoric landscapes are large transport infrastructure projects in southern Scandinavia. Denmark and Sweden especially have invested large sums of money to improve their transport-systems during the last three decades by replacing traditional ferries with bridges and tunnels. The connections from the Danish island of Funen to Zealand over the Great Belt (1988-1998), or from Zealand to Skane in Sweden crossing the Øresund

(1991-2000), are pioneering works, not only in terms of engineering, but also in the integration of research on prehistoric landscapes and archaeological sites during the construction phases. The results achieved have considerably widened our knowledge about the prehistoric settlement history (Pedersen *et al.,* 1997).

Against this backdrop, it was already accepted that submerged prehistoric landscape research and heritage management should form an integrated part of the planning during an ambitious and ongoing construction project to connect the Danish island of Lolland with the German Fehmarn Island by a tunnel through the Fehmarnbelt. Since 2008, as part of the general Environmental Impact Assessment, extensive geological, geophysical, biological and archaeological investigations have been underway in the waters of the Fehmarnbelt as well as in the affected coastal zones.

In support of this project a number of geophysical surveys using seismic and side-scan sonar equipment were carried out primarily to obtain a clearer understanding of the stratigraphic sequence of the seabed. They were followed by an extensive programme of geological boring leading among other things to the discovery of well-preserved peat layers, covered by limnic-fluviatile and overlying marine sediments. Pollen and diatom analyses in combination with geochemical screening show clearly that, prior to the marine transgression of the landscape during the Littorina stage some 8,000 years ago, a fresh-water lake existed here, originally positioned in the hinterland far back from the coast. Today this submerged lake represents an important archive of landscape history. All costs for the archaeological and palaeoenvironmental investigations will be borne by the construction company.

Credit: S. Wolters/ NIhK Wilhelmshaven

Fig. 4.10 Retrieval of sediment cores in the Fehmarnbelt-project for geological and palaeoenvironmetal investigations.

The rapid development of the offshore renewable energy industry has provided the opportunity to develop appropriate regulations and practices at an early stage. One such new code is the Offshore Renewable Protocol for Archaeological Discoveries (ORPAD) in the UK (Crown Estates, 2014).

Predictive modelling in Marine Spatial Planning

The integration of the archaeological record in spatial planning on land is, in almost all European countries, based on the available information about archaeological finds and features of scientific significance, whether salvaged or documented by amateur archaeologists or volunteers, discovered in the course of research projects, heritage excavations or during construction works as chance finds.

In Germany some 1.3 million find spots of different age and preservation status are registered, meaning that on average three sites are known for every square kilometer of land (Jöns, 2013). Around 10% of these sites are dated to the prehistoric period. Archaeological excavations conducted in the context of laying gas pipelines or construction of new roads or highways, have in many cases shown that for every ten sites located on the track surveyed, only one or two were already registered before in the heritage archives. On this basis it could be predicted that the real concentration of sites in Germany is in the range of 20 to 30 sites per square kilometre, two to three of them probably originating more than 5,000 years ago during prehistoric periods. Although at present there are no available statistics, similar numbers may be estimated for most other European countries. Consequently, for the submerged parts of the continental shelf that were settled in prehistory, comparable numbers may be assumed by extrapolation.

The estimated number of sites contrasts strongly with the number of submerged prehistoric finds actually discovered and registered, so that one might mistrust this calculation. But when compared to the numbers of prehistoric sites, known from intensively investigated submerged areas such as the Bay of Wismar in Germany or the waters around the Danish islands Funen and Lolland/Falster, it becomes obvious that the estimated number of sites should be considered as realistic. However, in some other areas, depending upon local conditions during marine transgression, a varying proportion of the sites that originally existed may have been eroded or scattered.

In offshore areas, deeper water, or areas that are subject to strong currents, poor visibility, or high rates of sedimentation, sites may only be discovered and identified by chance. This may be when erosion is just beginning to uncover them or where, for example, construction works or bottom trawling have done so. Consequently, many submerged prehistoric sites cannot be protected from natural erosion, so that a logical system for measurement and abandonment must be accepted. Indeed we have to face the threat that many of these archives will be exposed and destroyed without being discovered, not to mention being documented and thoroughly investigated. Protection and preservation is only possible in some special and extraordinary cases.

Our knowledge about the topographic settings favoured by prehistoric communities for settlement, fishing, hunting or gathering, may be used to predict where to expect prehistoric remains elsewhere. This kind of predictive modelling is highly dependent on the quality and resolution of the available data and information about the original landscape and environment occupied by our prehistoric ancestors. Therefore detailed geophysical and geological investigation of the seabed and large-scale documentation of the submerged landscape become indispensable for the development of plausible models (Chapter 5).

These data should indicate in which submerged areas there is a high probability for the survival of well-preserved settlement and landscape indicators. This might be the case when the prehistoric landscape comprised rivers or shallow bays adjacent to sandy and dry spots, offering favourable conditions for the building of huts and fireplaces as well as for the control of nearby fishing fences, traps and bird nets. If these locations were not directly exposed to the wind and weather of the open sea, they would have been very attractive to the prehistoric communities for building specialized, temporary camps for fishing, hunting or gathering roots, fruits and nuts. For such locations offering favourable living conditions we can expect the establishment of base camps that stayed in use for generations.

Predictive models can also identify areas with relatively low archaeological potential. This might be true for areas where the reconstructed palaeolandscape was probably unattractive for prehistoric settlement and subsistence activities. For example, sandy areas and dry plains, positioned far away from permanent water supplies played a comparatively small role as living space for prehistoric societies. Also, in areas with originally attractive living conditions, the probability of finding well preserved prehistoric submerged landscapes and sites might be very small if they experienced strong erosion and relocation of sediments. This can happen in the case of both natural and human-induced erosion.

Predictive modelling will neither replace future research nor will it make a sensible recording of finds and structures on the seafloor dispensable, but it may help to focus the scientific attention on those submerged areas that probably contain important and unique information about prehistoric life, landscape, sea level and climate. The location of every new site or landscape element may lead to a calibration and improvement of the relevant model, so that predictive modelling should be considered more as a continuously refined process, rather than as a time-limited project.

In the western Baltic waters of Denmark, Sweden and Germany, in areas where geophysical and geological data allow a high resolution reconstruction of the topography and environment that prehistoric people occupied, predictive modelling has already successfully been used for the location of prehistoric fishing camps or settlements. The submerged sites already described in the German Bay of Wismar or around the Danish islands are examples. More recently, predictive modelling has become an important tool for the location of submerged prehistoric sites in the North Sea, and is being integrated into Marine Spatial Planning. Currently, projects in Belgium, the Netherlands and Germany are preparing highly robust predictive maps to be integrated into Environmental Impact Assessments and also in actual engineering projects. This approach has produced convincing results as the example from Maasvlakte II at Rotterdam has shown.

Human capacity building and sector skill alliance

Continental Shelf Prehistoric Research requires a permanent structure with educational and training support and interaction with other relevant research communities. This is in line with the target of the Erasmus+ Knowledge Alliance to boost innovation and stimulate the flow and exchange of knowledge between higher education and enterprises. This will also encourage Capacity Building to tackle skills gaps for sustainable development; Sector Skill Alliance may be a beneficial mechanism to advance this process.

4.3 Actions to tackle

We are facing a situation where submerged archives of high importance for the prehistory of Europe are in danger of being lost without being known. It is essential to design a research and communication strategy that will be the basis for a systematic compilation, documentation and analysis of the submerged prehistoric landscapes. To reach that goal the following actions should be taken:

I. Exchange of best scientific practice

SPLASHCOS has illustrated the wealth of knowledge and experience across many different disciplines which can be effectively aligned through collaborative research projects. International and interdisciplinary collaboration, especially in the fields of marine geology and geophysics, biology and archaeology, is essential for future work in submerged prehistoric landscape research. Interdisciplinary cooperation should not only be focused on fieldwork such as surveys, sampling and excavations, but also on the preparation of public access and visualization of the results through different media ranging from scientific publications to newspaper articles, film or TV programmes.

II. The benefits of cooperation

It will be of high importance to build a sustainable network with other professional and volunteer actors working in European marine waters. The fishing industry is continuously salvaging terrestrial mammal bones, chunks of peat (moorlog) and single archaeological artefacts as by-products of the catch. Only a few countries require a systematic registration of this material, which can provide a useful indiction of the location of submerged prehistoric landscapes and sites, as well as their dating and environmental conditions. Increased cooperation between archaeologists, geologists and palaeontologists on the on hand, and fishing and dredging industries on the other will be cruicial to ensure opportunities are not missed. The SPLASHCOS contact list must be maintained, and sessions on prehistoric archaeology planned in the IKUWA and EAA conference series, while European seabed mapping and marine geology programmes should be developed to include prehistoric landscapes.

In addition to fishing, close cooperation is also needed with the offshore oil and gas industry. Hydrocarbon exploration normally begins with intensive geological and geophysical surveys to obtain data about stratigraphy and the consistency of the bedrock, but the same data can also facilitate a reconstruction of submerged landscapes in high resolution. In addition, the drilled cores from these investigations may allow geochemical, palynological or macrofossil analyses and dating, which can, in turn, provide important information about the local landscape and sealevel history. The Doggerland-project, an example of fruitful cooperation between marine industry and research, integrated datasets from the geophysical marine service industry of the UK-part of the EEZ to model the prehistoric landscape of the Dogger Bank and western central North Sea (Gaffney *et al.,* 2009). The existing experiences in cooperation between science and industry are very promising and show, not only that previously measured and stored data are of extremely high value, but also that cooperation leads to industrial managers having a better understanding of the scientific interests of submerged landscape research.

III. High quality data

A key objective is the improvement of the quality and availability of detailed maps of preserved seabed structures that may indicate palaeolandscapes. Through projects such as SeaDataNet[32] and long-term initiatives such as EMODnet[32], the European Commission has supported development of web-based data management for large and diverse datasets from *in situ* and remote observation. The system links the databases of the professional marine data centres of 36 countries. This pan-European network provides commonly accessible on-line integrated databases of standardized quality and is of high importance for the Continental Shelf Prehistoric Research. But access to data at the level of distinct data sets still does not produce integrated and consistent maps to uniform standards without a great deal of extra work. Chapter 5 of this paper addresses this stage of European marine data management in more detail.

It is still a big challenge to improve the quality and resolution of seabed data. Large quantities of acoustic data have been produced by marine industries that often remain classified or confidential, even though they may have no remaining commercial value. Research effort is needed to integrate fragmented industrial data and to close the gaps with new data of high resolution, so that bathymetric and sediment/rock data can be interpreted and used for visualization of landscape features.

IV. Expansion of predictive modelling

Results achieved so far have proven that predictive modelling is an effective tool both for research and for Marine Spatial Planning. This is especially the case for areas where direct detection of submerged settlement relics is more or less impossible because they are covered by sediments or are invisible for other reasons. Common approaches to Marine Spatial Planning across European continental shelf would also benefic prehistoric submerged landscape research.

Calibration and trials of offshore predictive modelling are essential to check the incidence of success in predicting site occurrence, and the incidence of false positives and false negatives. If this is done carefully, then predictive modelling can be used in well-controlled cases as a substitute for extensive and expensive field-work. This check on the reliability of modelling needs to be done in areas where sites are already known.

Although high resolution predictive modelling has so far only been used in a few submerged areas of the European shelf to predict the location of single sites, it could already be used to distinguish areas of high archaeological potential from those of little of no potential in areas such as the western Baltic, parts of the North Sea and the Mediterranean Sea.

[31] http://www.seadatanet.org/
[32] http://www.emodnet.eu

V. Training the next generation

Special interdisciplinary field courses organized by the SPLASHCOS Action have shown that students and early stage researchers are well motivated to participate in high standard courses. The establishment of interdisciplinary university courses which include underwater excavation and mapping, recording and conservation of artefacts, as well as acoustic surveys, sea-level modelling and palaeoenvironmental and geochronological analysis of palaeocoastlines, would lay a solid foundation for the future of Continental Shelf Prehistoric Research.

The courses should also be open to young technicians and engineers embarking on careers in the offshore industry. Training a new cohort of graduates who understand the special technical requirements and needs of the research on submerged landscapes and sites will support the development of new technologies, sampling and research methodologies, especially in areas with depths of more than 10-20m and with low visibility. Senior academic appointments in the field of prehistoric landscape research could also be an important mechanism to advance this developing field. For example, by the granting of an endowed professorship, with associated tied funds as a research hub plus adjunct positions. It could be installed in an institute for marine geology, archaeology or engineering at a European university with available technical equipment required.

Fig. 4.11 As part of the SPLASHCOS COST Action, early stage researchers took part in training run by the Hampshire and Wight Trust for Maritime Archaeology, gaining experience on the unique underwater Mesolithic site of Bouldnor Cliff (UK).

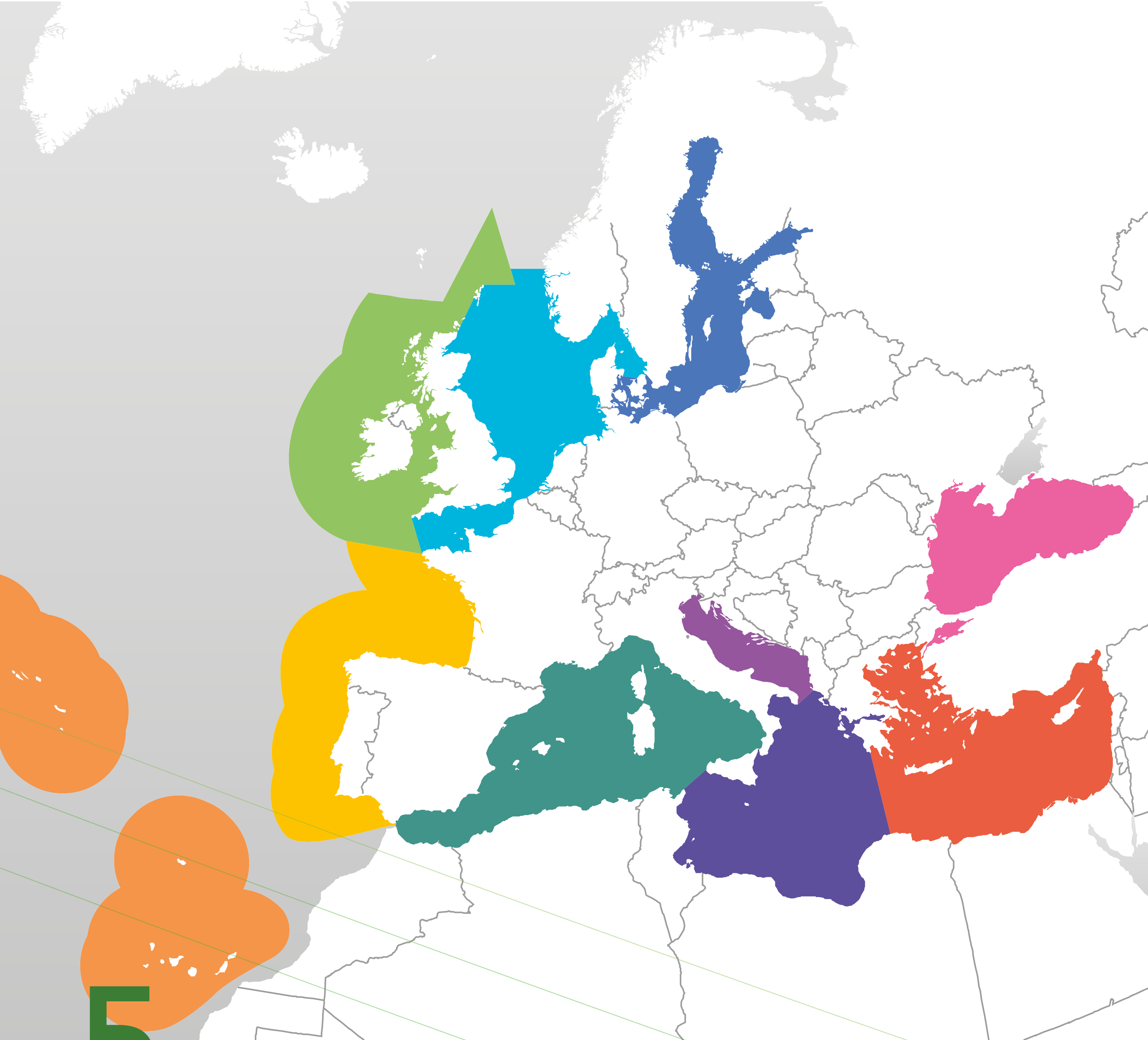
Credit: SPLASHCOS Project

SUMMARY

Advancing Continental Shelf Prehistoric Research will require further enhancement of cross-disciplinary cooperation between the diverse research interests and also between the research community and other stakeholders, especially offshore industry. Stable teams of highly- and multi-skilled researchers are needed with permanent access to the technical equipment and data essential for safeguarding, investigating and studying submerged prehistoric sites and landscapes as well as promoting and visualizing the results.

Support should be targeted at the following specific issues:

- Open access to research and public monitoring data and the sharing of data between industries and research;
- Improved cooperation between industry and science in the development of excavation, sampling and documentation techniques;
- Better use of archaeological sites as sea-level index points;
- Development of postgraduate university courses for archaeology, geology, geophysics and technical engineering;
- Appointment of professorships in submerged prehistoric landscape research;
- Integration of predictive modelling into European marine spatial planning;
- Integration of submerged prehistoric landscape research as a research objective of the European research programmes.



Credit: MSFD DIKE 5/12/08

5

Europe's regional sea basins and data resources

This chapter summarizes the key features of Europe's regional seas and coasts and is intended to help archaeologists, who may only have a cursory knowledge of any particular sea, to understand the differences between the marine environments around Europe and to provide an overview of the sources of information that are available to support their research. Previous chapters have shown that location and survival of submerged prehistoric sites depend on the local geomorphological conditions. The original location of prehistoric sites in the palaeo-landscape, the subsequent erosion or preservation of the sites and the surrounding terrain, and the chances of survival and discovery, are determined by the geology, sedimentary history and oceanographic conditions of the local sea area. Given the considerable differences between the European sea basins and the variable evolution of the seabed and sedimentary structures, researchers studying the prehistoric occupation of the continental shelf need access to specialized regional and local data at high resolution. The present landscapes of northern Europe were sculpted by the advance and retreat of ice sheets during the last 2.6 million years whereas those of southern Europe were formed by the interplay of periodically fluctuating sea level, caused by melting of the northern ice sheets, and long-term tectonic activity. Underlying the sediments found on the seafloor are rocks spanning more than 4 billion years of Earth's history. There have been recent initiatives aimed at bringing together information on the water depths (bathymetry) around Europe and the geology of the coasts, seafloor and the rocks and sediments that underlie the seabed. These provide an overview of Europe's marine environments, to complement the information that exists at regional level, and provide an introduction to the key features of each sea area for the non-specialist.

- Macaronesia
- Bay of Biscay and the Iberian Coast
- Celtic Seas
- Greater North Sea
- Baltic Sea
- Western Mediterranean Sea
- Ionian Sea and the Central Mediterranean Sea
- Adriatic Sea
- Aegean-Levantine Sea
- Black Sea

5.1 Current understanding

The European seas can be subdivided into 7 regions from the Baltic Sea through the Greater North Sea; Celtic Seas; Bay of Biscay and the Iberian Coast; the Macaronesian biogeographic regions around the Azores, Madeira and the Canary Islands; the Mediterranean Sea and the Black Sea. Europe is also bordered by two oceans, including the Arctic Ocean to the north and the Atlantic to the west. Each sea region can be further subdivided into semi-enclosed basins with distinct geology and oceanography such as the sub-basins of the Mediterranean Sea, which include the Western Mediterranean, the Ionian and Central Mediterranean Sea, the Adriatic Sea and the Aegean-Levantine Sea.

The regional seas display a wide range of water depths, geology and processes that have shaped the morphology of the coasts and seafloor. The Baltic Sea is almost completely enclosed and is mostly shallow (average depth 52m; maximum depth 459m) and has an areal extent of about 418,500km^2. The Greater North Sea is mostly shallower than 100m in depth with many areas less than 50m in depth in the southern North Sea. The Celtic Seas have similar water depths on the continental shelf, deepening to the west into the Atlantic Ocean. The Bay of Biscay covers an areal extent of about 223,000km^2. The estimated average depth is 1,744m and the greatest depth is 4,735m. Off the coast of France the shelf extends about 140km off Brittany but narrows along the Spanish coast to about 12km. The Mediterranean Sea is almost completely enclosed by land. Its average depth is about 1,500m and the deepest recorded point is 5,267m in the Ionian Sea. The Mediterranean stretches over 4,000km from the Straits of Gibraltar to Israel and covers an area of more than 2.5 millionkm^2. The Black Sea is the largest anoxic basin in the world with a maximum depth of about 2,250m, an average depth of 1,240m, and surface area of 4.2×10^5km^2. The sea is about 1000km in an east-west direction and 400km from the north to south.

Seabed substrate

The seabed substrate and shallow sub-seafloor geology include recent superficial sediments and areas of exposed older rocks and sediments. Surface sediments are derived from erosion of the European landmass and the exposed substrate, and are deposited by modern oceanographic and coastal processes. The sub-surface consists of rocks and sediments of Quaternary age or older. The significant sub-seabed succession in terms of palaeolandscapes that have influenced archaeological developments is the Quaternary – a period that started about 2.6 million years before the present day. To reconstruct the precise timing and extent of the glacial events, sea-level changes, palaeoenvironments and palaeogeography, a stratigraphic model for the Quaternary geology of Europe is required using existing geophysical data and cores to constrain timing and to identify sites for chronological analysis. From this, a high-resolution chronological framework for a regional landscape evolution model can be made. Such a framework would be used to test if established chronology onshore from known sites of archaeological importance can be linked to the offshore record and the offshore palaeogeography of the Mesolithic-Neolithic areas and older. Where possible, the thickness of Quaternary and Holocene sediments should be recorded. Recent geological events such as faulting and volcanic activity in the Mediterranean area have associated vertical land movements that have caused very fast local relative sea-level changes leading to the submergence or uplift of areas of past habitation.

Coastal behaviour

The coastal boundary between the land and sea is a transient, dynamic feature created by a combination of sea-level fluctuations, tectonic movements, sedimentation and erosion that force the coastline to migrate vertically and horizontally through time. What is the relevance of current coastal behaviour in the European seas? Can present-day conditions be related to coastal change through human history? The exposure of very early prehistoric sites on the shore at Happisburgh (See Ch. 3) and the continuing slow inundation of the south Baltic coast, illustrate the relevance of understanding present processes. Rivers provide considerable amounts of terrestrial material to coasts. These sediments, together with those derived from coastal erosion, provide material for offshore reefs, mudflats, salt marshes, beaches, dunes, etc. Projects such as EUROSION (see Section 5.3) have assessed 13 indicators – 9 indicators of state and pressure (sensitivity) and 4 indicators of impact – to quantify different factors that characterize or exacerbate coastal erosion processes. These are presented as areas ranging from 'very high exposure' to 'lower exposure'.

Glacial history of northern Europe

During ice-age glacial maxima of the last ~2.6 million years, ice sheets have covered large portions of the northern hemisphere (Fig. 5.1) and the resulting changes in sea level have been discussed in Chapters 1 and 2. Records from the retreat of these ice sheets during periods of melting and deglaciation provide important insights into how ice sheets behave under a warming climate. During the last two deglaciations the southernmost margins of land-based northern hemisphere ice sheets responded almost instantaneously to warming caused by increased summertime solar energy reaching the Earth. In contrast, marine-based ice sheets experienced a delayed onset of retreat relative to warming from increased summertime solar energy, with retreat characterized by periods of rapid collapse. Bose *et al.* (2012) have reviewed the extent and chronology of glaciations in northern Europe. Responses of glaciation to global climate change can be expressed in terms of marine isotope stages (MIS) and, where possible, sub-Milankovitch changes such as Heinrich events (events during which ice broke off from glaciers which dropped ice rafted debris as they melted).

Credit: NASA World Wind/ Post-Glacial Ice Cover Add-on

Fig. 5.1 Ice cover in northern Europe at the Last Glacial Maximum

Sea-level change

Local relative sea level change is the cumulative effect of eustatic-glacial hydroisostatic processes (GIA) and local tectonics (see Chapter 2). Eustatic sea-level fluctuations juxtaposed to the effect of long-term geological processes have always defined the limits of landmasses and the sea (Fig. 1.2). Glacial hydroisostatic modeling has been successful in understanding the detailed migration of the shoreline in tectonically stable areas (e.g. Western Europe, Atlantic shelf and Northern Europe). However, in tectonically active areas such as the Eastern Mediterranean Sea, and particularly the Aegean Region, plate tectonics have led to vertical tectonic movements at the regional or even local scale.

In the context of recent human history, the early Holocene was a time of widespread environmental change as temperatures rose rapidly at the end of the last glaciation. Although Holocene sea-level change is not well understood, it is known that it has not been uniform across all European shelf areas. A notable feature of Holocene sea-level change was the approximately 60m rise in sea levels over most of the Earth as the volume of ocean water increased. The causes of this sea-level rise and the effect it had on ocean current patterns, the decay of coastal ice streams and the coastline require further research. In addition, the relationship between sea-level change and climate, volcanic activity and submarine sliding (and related tsunamis), and the impact on Mesolithic and Neolithic cultures, are also priorities for research in Europe.

Flemming (2002) observed several factors that favour archaeological survival during inundation as sea level rises: the critical period for survival of archaeological deposits is when the surf zone impacts on the site and during the few hundreds of years after, when the site is in shallow water.

Factors which favour archaeological survival include:

- Very low beach gradient and offshore gradient, so that wave action is attenuated and constructional in the surf zone. Minimum fetch so that wave amplitude is minimal, wave length is short, and wave action on the seabed is at a minimum.

- Original deposits to be embedded in peat or packed lagoonal deposits to give resistance and cohesion during marine transgression. Drowned forests and peats are good indicator environments.

- Where deposits are in a cave or rock shelter, roof falls, accumulated debris, concretions, breccia, conglomerate formation, and inundation by wind-blown sand, may all serve to secure the archaeological strata.

- Local topography with indentations, re-entrants, bays, estuaries, beach-bars, lagoons, near-shore islands, or other localized shelter from dominant wind fetch and currents at the time of transgression of the surf zone.

The survival of an archaeological deposit during transgression therefore depends on the local topographic conditions (see Chapter 2). Given that maps showing the earlier geological periods that may contain palaeolandscapes of interest to archaeologists are generally of low resolution, determining the preservation of archaeological relics is problematic. The wide use of multibeam echosounder systems to map many areas of the European seabed is leading to high resolution mapping of the topography of the coastline and seafloor and helps to select coring sites that can improve our knowledge of Quaternary chronology.

Methodologies and ice-sheet modelling

Methodologies that are applied to understanding the glaciations of northern Europe include studies of lithostratigraphy and morphostratigraphy, which have been enhanced by recent improvements in understanding glacial depositional processes, and computer techniques that represent stratigraphically significant aspects of landforms on land and the seabed. Chronological methods such as radiocarbon dating and amino-acid racemisation have improved the resolution of determining glacial history, and optically stimulated luminescence (OSL) or cosmogenic radionuclide dating of glacially derived sediments and abraded surfaces have fundamentally changed the approach to glacial chronology. Numerical ice-sheet models in areas of glaciated terrain (e.g. Boulton and Hagdorn, 2006; Hubbard *et al.,* 2009 models of the British and Irish ice sheet) provide simulations that can be compared to field data.

Palaeolandscapes

During periods when land has emerged in response to sea-level fall, fluvial processes (and peri-glacial processes in ice-marginal settings) are the principal factors that shape the landscape. Deposits preserved in these settings are limited to former river valleys and interfluves/terrace landscapes. Coastal landscapes are only partially preserved due to reworking and erosion during transgression. However, recent studies have uncovered evidence of an increasing number of Holocene coastal landscapes, and submerged cliff coasts have been frequently documented. Stratigraphic and sediment analysis of submerged landscapes can constrain, for example, the rate of sea-level rise that led to submergence of coastal landforms. A review of different types of environments should consider specific environments in which prehistoric sites survive.

Archaeology

Key factors in determining archaeological importance are the size and shallowness of the seas. During sea-level lowstands, broad shallow areas are exposed creating landscapes with potential for human habitation. From an archaeological and palaeoenvironmental perspective there is clear evidence of palaeolandscape preservation in the form of submerged river channels, associated terrace deposits, peats and terrestrial/freshwater sediments. Effective research requires a firm knowledge of the seabed and sub-seabed geology.

5.2 Key features of European regional seas

Baltic Sea

The Baltic Sea is a semi-enclosed almost tideless intracontinental sea surrounded by the Scandinavian landmass and by the lowlands of central and Eastern Europe. It is one of the largest brackish-water, inland seas in the world and it has undergone a complex and unique development after the last deglaciation. The area of the Baltic Sea is about 418,500km^2 with a catchment area approximately 4 times larger than the area of the sea itself, and the salinity is very low. The sea is shallow (average *ca.* 50m) with a shallow and narrow connection to the North Sea and Atlantic Ocean through the Danish Straits. The topography of the seabed includes a number of basins divided by seabed 'highs' and escarpments. Shallow-water areas include banks with a minimum depth of 8m.

During the Pleistocene, ice advanced several times into the area of the present Baltic Sea, eroding the bedrock and deepening the Baltic Sea Basin (BSB). A pathway between the BSB and the Barents Sea existed during the first ca. 2,500 years of the Eemian interglacial (130–115 ka BP). Houmark-Nielsen and Kjær (2003) and Houmark-Nielsen (2007, 2008) concluded that the SW Baltic may have experienced two major ice advances during MIS 3, at ca. 50 and 30 ka BP. Glacial rebound modeling predicts that the BSB was fully glaciated around 38 ka BP and became ice-free around 35 ka BP (Lambeck *et al.,* 2010). The Last Glacial Maximum (LGM; MIS 2) about 20 ka BP was the coldest phase of the last glacial cycle, when the ice was at its highest volume.

Retreat of the Scandinavian Ice Sheet (SIS) since the LGM was non-monotonic and was influenced by climatic oscillations of the Bölling/Alleröd Interstadial (14,700-12,700 BP) and the Younger Dryas cold period (12,800-11,500 BP). In the area of the southern part of the present Baltic Sea, the ice sheet melted and the Baltic Ice Lake was formed approximately 16,000 years ago (Andren *et al.,* 2011) while deglaciation of the northern Baltic took place much later, around 10,500 BP (Linden *et al.,* 2006). Following the last deglaciation, the Baltic Sea area experienced two lake phases (the Baltic Ice Lake (16-11.7 ka BP) and Ancylus Lake (10.7-9.8 ka BP) alternating with marine phases (Yoldina Sea and Littorina Sea). The interplay between the rate of isostatic uplift and the rate at which sea level was rising resulted in the area being raised above sea level, leading to the ponding that created this large glacial lake. The first drainage of the lake probably took place about 13,000 years ago as ice receded northwards followed by a second ponding episode related to Younger Dryas cooling at ca. 12.8 ka BP. Ice retreat at the end of the Younger Dryas caused sudden lowering of the Baltic sea level by about 25m, which had a huge impact on the circum-Baltic environment, with large coastal areas suddenly subaerially exposed, large changes in fluvial systems, considerable reworking of previously deposited sediments, as well as the establishment of a large land-bridge between Denmark and Sweden.

Saline water entered the Baltic during the Yoldia Sea stage. Although the Yoldia Sea was at level with the open sea already at 11,700 years BP, it took ca. 300 years before saline water could enter into the basin. The high uplift rate together with the high volume of outflow from the lake prevented further entry of saline water, which led to the Yoldia Sea becoming at a later stage again a freshwater basin with limited connection to the ocean. The duration of the brackish phase has been estimated only to 350 years and therefore most of the time the Yoldia Sea has been a freshwater body (Andren *et al.,* 2011). As the Yoldia stage ended, the next stage in the updamming of the region began in the southern Baltic with the Ancylus Lake (10.7-9.8 ka BP) transgression, which is evident from submerged pine trees and peat deposits dated between 11.0 and 10.5 ka BP. Dramatic changes in the Baltic Sea ecosystem took place during the early Holocene as the Ancylus Lake drained into the ocean and allowed saline water to enter the Baltic Basin to form the Initial Littorina Sea (9.8-8.5 ka BP) and Littorina Sea (8.5 ka BP - present). About 8,500 years ago the Baltic Sea became a brackish water basin with significantly increased primary production (Andren *et al.,* 2011) establishing favorable conditions for early humans to exploit marine resources and develop coastal settlements (Jöns, 2011).

Melting of the Scandinavian Ice Sheet (SIS) changed the mass load on the continent and in nearby oceans, including the Baltic Sea, and resulted in isostatic adjustments throughout the region. Records of relative sea level (RSL) differ from place to place and with time because of the interaction between eustatic sea-level rise and postglacial rebound process (Fig. 5.2).

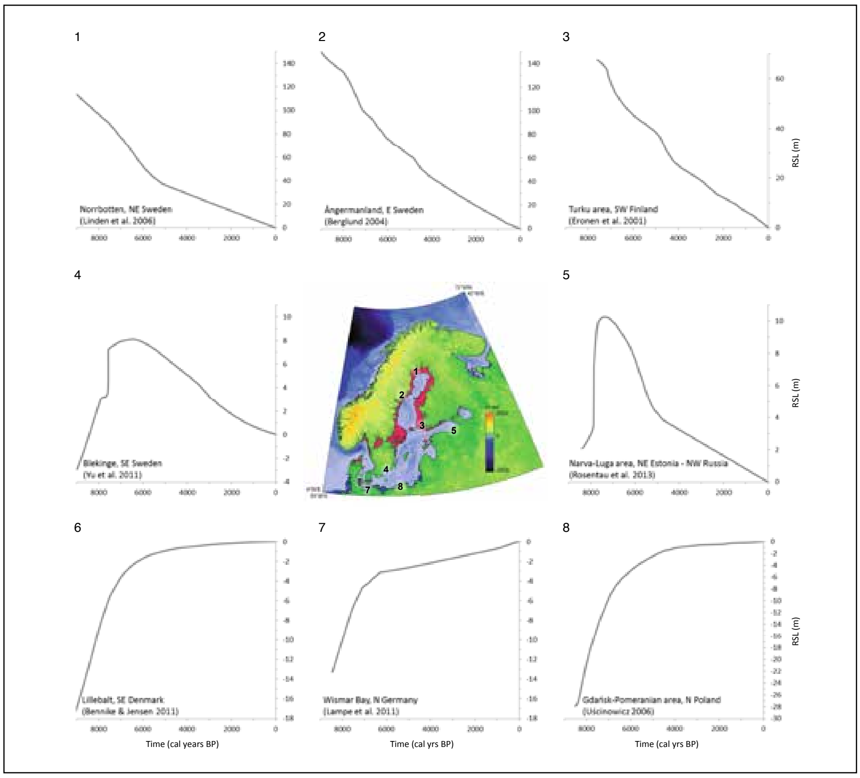


Fig. 5.2 The change of coastline and relative sea level in different parts of the Baltic Sea basin since the onset of the Littorina Transgression about 8,000 years ago. Red colours mark areas of regression and blue colours of transgression (modified from Harff *et al.,* 2007).

In the northern Baltic Sea, in the areas of the Bothnian Sea and the Bothnian Bay, uplift has exceeded the eustatic water-level rise throughout the period since deglaciation. Marine regression has occurred leading to emergence of the seafloor to become land (Fig. 5.2), which still continues today. The highest coastlines in the region corresponding to the updammed Ancylus Lake stage (Fig. 5.3) which have been elevated to a height of about 250 metres above the present sea level since the time of deglaciation (Berglund, 2004) while highest Littorina Sea coastlines are at elevation about 150 metres above present sea level (Fig. 5.2).

Fig. 5.3 Palaeogeography of the Ancylus Lake during transgression maximum at ca. 10.5 ka BP (Andren *et al.,* 2011).

Areas of southern Denmark, and the coasts of Germany, Poland and Lithuania, were affected by marine transgression during the Holocene. The sea flooded land areas, eroding glacial and glaciofluvial sediments, as well as terrestrial sediments that formed after ice-sheet retreat (see e.g. Uścinowicz, 2003 & 2006). In places, Stone Age artefacts, relics of lacustrine sediments, peats and even tree trunks rooted *in situ* occur here on the seafloor. Offshore geological and archaeological studies in this area have revealed a large number of Stone Age artefacts and the remains of settlements that are now submerged as a result of marine (Littorina) transgression, both off the Danish coast (Fischer, 2011) and the German coast (Lübke *et al.,* 2011). Off the coast of northern Germany, tree stumps are found at a number of sites. A large number of finds from Wismar Bay have been dated (Lampe *et al.,* 2005). In Denmark, tree stumps are known from many areas by local fishermen, but only a few have been sampled and dated (e.g. Fischer, 1995). At about 9000 years old drowned forests with preserved rooted tree stumps have recently been discovered in the Gulf of Gdansk at about 6-7 km offshore at water depths of 16-17m (Uścinowicz *et al.,* 2011). Submerged tree stumps have also been found at three sites off the Lithuanian coast. Calibrated radiocarbon ages of stumps range from 11,000 years BP to 7,800 years BP (Zulkus and Girininkas, 2012).

The central Baltic Sea coast, from Scania to Stockholm in Sweden and the coasts of Latvia, Estonia and southern coasts of Finland, have had a more complex Holocene shore displacement history. Coastal transgressions took place here in connection of Ancylus Lake updamming and when rapid glacio-hydro isostatic sea-level rise exceeded the local rate of uplift at the beginning of the Littorina Sea (Fig. 5.2). Coincident with the slowing of eustatic rise towards the end of the Atlantic period, uplift processes started to prevail leading to coastal regression (e.g. Miettinen, 2004; Veski *et al.,* 2005; Yu *et al.,* 2007; Rosentau *et al.,* 2013). In Sweden, one of the best documented sites with submerged tree stumps is found in Hanö Bay, from where pine stumps from depths of 13–14m have been dated to the pre-Ancylus transgression period (Gaillard and Lemdahl, 1994). In the eastern coast of the Gulf of Riga buried peat layers have been documented in the bottom of the Pärnu River valley at a depth of 3.8 m bsl and dated to c. 9,500 cal yrs BP (Rosentau *et al.,* 2011). In the same area c. 10,800 and c. 9,000 years old Stone Age cultural layers have been uplifted few metres above present sea level and covered in present-day by Ancylus Lake and Littorina Sea sediments, respectively (Veski *et al.,* 2005).

Greater North Sea

The Greater North Sea is a marginal sea of the Atlantic Ocean surrounded by the United Kingdom, Scandinavia, Germany, the Netherlands, Belgium and France. It connects to the ocean through the English Channel in the south and the Norwegian Channel to the north. It is more than 970km long and 580km wide, with an area of around 750,000 km^2.

The marine area contains a record of submerged prehistoric landscapes from a variety of periods between 700,000BP and 5,000BP, which were once an extension of the terrestrial landscape. Whilst the area is currently a marine zone, it would have constituted dry land for considerable periods of time, when it would have been occupied by hominins. The deposits relating to these landscapes therefore not only have the potential to contain archaeological material, but also to have archaeoenvironmental significance through the preservation of landscape, climate, and environmental data.

The presence of earlier landscapes (700,000BP to 18,000BP) is problematic within the region as these have been modified by repeated marine transgressions, glaciations and subaerial erosion. The presence of early hominins in Britain during this period indicates that there is a potential for Palaeolithic artefacts. These are most likely to be derived from secondary contexts due to the high level of erosion and reworking in this area, however, some *in situ* deposits are present (Wessex Archaeology, 2012). As such, the most likely form of archaeological potential relates to the submerged landscape of the Late Palaeolithic to Mesolithic (18,000 to 6,000BP) which developed after the Last Glacial Maximum at 20,000 BP.

During the Elsterian (~450 ka BP), land ice blocked northward drainage from the southern North Sea into the Norwegian Sea (e.g. Huuse and Lykke-Andersen, 2000). The existence of a landbridge of high ground between France and the British Isles across the present straits of Dover-Calais (the Weald-Artois ridge) caused a large freshwater lake to develop in the area to the south of the ice front. During this period, glacial meltwater eroded deep valleys under the ice sheet, some cutting as much as 400 m into the subsurface (Praeg, 1997). Similar valley systems can be traced southwards onshore. Overspill of water from the Elsterian southern North Sea Lake carved a deep channel in the Weald-Artois landbridge, which was subsequently widened by marine erosion to form the Strait of Dover. This channelling was thought by Gibbard (1988) to have taken place during successive periods of lake overspill, but Gupta *et al.* (2007) have proposed that it was formed in a single catastrophic breaching.

Changes in sea level during the period 18,000 to 6,000 BP are much better understood than for the preceding periods. At the beginning of the Late Upper Palaeolithic, around (18,000 BP) the northern North Sea area was still covered by ice sheets. Lambeck (1995) shows areas free of ice between 18,000 and 16,000 BP. Following the Last Glacial Maximum at 20,000 BP, the amount of total ice melted by 18,000 BP resulted in glacial rebound causing the region to rise faster than global sea level and thus the area remained emergent during this period. Emergence of areas of the seabed would have increased the amount of land available for human occupation and represented the route by which Britain would have been repopulated after glaciation during the Late Upper Palaeolithic (Pettitt, 2008). The low-lying landscape would have attracted hunter gatherers as it offered a range of food and other resources (Coles, 1998). As glacial rebound slowed, the rate of relative sea-level rise increased leading to inundation, before slowing again in more recent times.

Sea-level curves (Shennan *et al.,* 2000) show that the majority of the southern North Sea landscape was emergent from the beginning of glacial retreat at about 16,000 BP (Late Upper Palaeolithic) to approximately 7,000 BP (Late Mesolithic) when most of the landscape was inundated. At around 13,000 BP the area became ice-free and was subaerially exposed. The landscape was very much a dynamic one during the period in which it was available for human occupation (from circa 13,000 BP). Whilst the relative topography of the area would have remained unchanged, the effects of progressive sea-level rise and climate change would have dramatically altered the appearance and resources of the area in which humans would have lived.

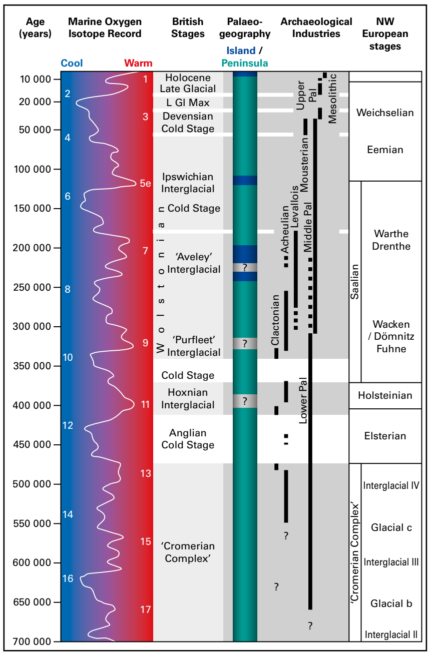


Fig. 5.4 Palaeogeography and oxygen isotope record with reference to glacial interglacial cycles and cultural periods. (After Tappin *et al.* 2011, based on Stringer, 2006 and Gibbard *et al.*, 2007)

As the ice retreated, glacial conditions were replaced by periglacial environments that influenced the vegetation cover. The landscape about 12,000 BP would have been tundra-like, comprising herbs and dwarf shrubs. As climate ameliorated at the start of the Holocene trees such as Scots' pine, birch and hazel expanded across the landscape. Around 8,000 BP other thermophilous trees such as elm and oak appeared, with alder and lime migrating by about 7,000 BP. This vegetation cover would have been strongly influenced by the rates and processes of marine inundation. The ingress of saline waters into the forested areas would have led to forest die-back, opening up areas of the landscape, with the remaining forest cover comprising the hardiest tree types.

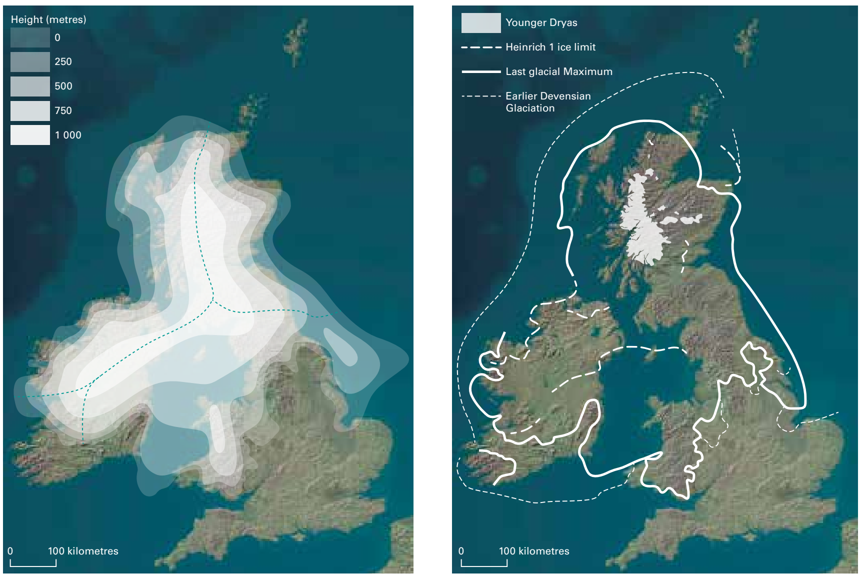
At the start of the Holocene 10,000 years ago, a large area of the present-day southern North Sea was land. The subsequent postglacial sea-level rise flooded the area, isolating the British Isles from the rest of the European continent. Shennan *et al.* (2000) showed that inundation began about 8,000 BP, and continued for ~2,000 years.

The Mesolithic landscape of the central and southern North Sea appears to have been a relatively low lying plain, sloping gently upwards towards the modern shoreline. During the Early Mesolithic, the landscape would have been relatively dry and well-wooded. However throughout the Mesolithic, increasing sea-level rise would have seen inundation of areas to initially form marshland and tidal flats in areas where marine inundation was rapid. Such environments would have expanded across the area throughout the Mesolithic before the landscape was entirely submerged. At the start of the Neolithic most of the area would have been inundated, with any remaining exposed areas probably forming extensive marshlands.

Within the Mesolithic landscape there are a number of significant features of archaeological interest. These include several major palaeochannel systems trending southeast–northwest with many smaller channels following a similar trend. Depressions in the region could have held bodies of freshwater.

There has been little change in the configuration of the North Sea coastline or drainage pattern of the land areas since about 5 ka BP. Erosional features indicate that earlier landscapes have been significantly affected by processes of erosion, which makes it difficult to identify their characteristics.

Fig. 5.5 Proposed extents of the last glacial maximum on the British Isles. (Tappin *et al.*, 2011, after Boulton *et al.*, 1991 and Bowen *et al.*, 2002)



At the end of the MIS 3 and throughout the MIS 2, the English Channel was a large alluvial plain flooded by a large river, the so-called Channel River. The river was formed by the confluence of most of northwest Europe's major rivers (Rhine, Meuse, Thames, Seine, etc.) (Gibbard, 1988; Lericolais, 1997, Hijma *et al.,* 2012). During this period a broad delta was developed at the outflow of this river (Berné *et al.,* 1998).

Celtic Seas

The Celtic Seas region is the area off the west coast of the United Kingdom, Ireland and northern France. It is bounded to the east by the English Channel and to the south by the Bay of Biscay. The western boundary is delimited by the continental shelf, which drops sharply to the Rockall Trough. Water depths are generally between 50m and 200m, extending to 1000m in the west. The Celtic Seas region contains wide variations in coastal topography, from fjordic sea lochs, to sand dunes, bays, estuaries and numerous sandy beaches. The coastline is predominantly rocky but with some areas of intertidal sediment occurring mainly in bays and inlets. The seafloor is mainly sand and gravel with rocky outcrops. There are seasonal variations in sea surface temperature, ranging from 8°C in winter to 18°C in summer. Some areas become stratified in summer and the strong tides generate tidal fronts, which influence water circulation. The probable post-LGM re-occupation of the western British Isles by northward migration from northern Spain and the Biscay coast (Oppenheimer, 2006) make this an interesting seabed, but the massive accumulation of modern marine sediments in the western approaches, and deep water, make future research problematic.

Bay of Biscay and Iberian coast

The Bay of Biscay faces directly onto the open Atlantic with depths at the order of 4,000m, and it is the continental shelf that is important for prehistoric research. Off the French part of the Bay, the continental shelf extends approximately 140km wide in the north off the Brittany coast, but narrows to about 50km in the south where France borders Spain. Along the coast of northern Spain, the shelf becomes even narrower extending only 2km from the coast. The mountains of northern Spain, the Cantabrian coast, contain numerous caves with some of the richest cave art in Europe. So far no sites have been found underwater. The shelfbreak occurs at water depths of about 200 m along most of the margin of the Celtic Seas and the Bay of Biscay beyond which is a steep slope with canyons, cliffs and deep-sea fans. The present surface current system is dominated by the northeast flowing Gulf Stream, which diverges into two branches off Ireland (Keffer *et al.,* 1988). One branch flows into the Bay of Biscay and another flow along the Irish margin. During glacial times, the Gulf Stream shifted southwards from its present position.

The coastline of the Iberian Peninsula is 3,313km, 1,660km on the Mediterranean side and 1,653km on the Atlantic side. The coast has been inundated over time, with sea levels having risen from a minimum of 115–120m lower than today at the Last Glacial Maximum (LGM) to its current level at 4,000 years BP. The coastal shelf created by sedimentation during that time remains below the surface; however, it was never very extensive on the Atlantic side, as the continental shelf drops steeply into the depths. An estimated 700km length of Atlantic shelf is only 10–65km wide. At the 500m isobath, on the edge, the shelf drops off to 1,000m.

The shelf drops into the Bay of Biscay on the north, the Iberian abyssal plain at 4,800m on the west and Tagus abyssal plain to the south. In the north, between the continental shelf and the Bay of Biscay, is an extension, the Galicia Bank, a plateau also containing the Porto, Vigo and Vasco da Gama seamounts, creating the Galicia interior basin. The southern border of these features is marked by the Nazaré Canyon, splitting the continental shelf and leading directly into the abyss.

Macaronesia

Macaronesia is a modern collective name for several groups of islands in the North Atlantic Ocean off the coast of Europe and Africa. The archipelagos consist of the Azores, Madeira Islands, including the Desertas Islands, Porto Santo Island, and the Selvagens Islands, the Canary Islands and the Cape Verde Islands. The islands of Macaronesia are volcanic in origin. To date no prehistoric remains have been found on the islands, and it seems unlikely that they would occur offshore.

Mediterranean Sea

The Mediterranean Sea is almost completely enclosed: to the north by Europe and Anatolia, on the south by North Africa and to the east by the Levant. It covers an approximate area of 2.5 million km² but its connection to the Atlantic (the Strait of Gibraltar) is only 14km wide. The Mediterranean Sea has an average depth of 1,500m and the deepest recorded point is 5,267m in the Calypso Deep in the Ionian Sea. The morphology of the shelf areas is influenced by the tectonic and sedimentary setting. In stable/uplifting areas starved of sediment there may be bedrock outcrops that create a complex setting of shoals and palaeo-headlands. In subsiding and sediment-fed areas the shelf is usually relatively flat.

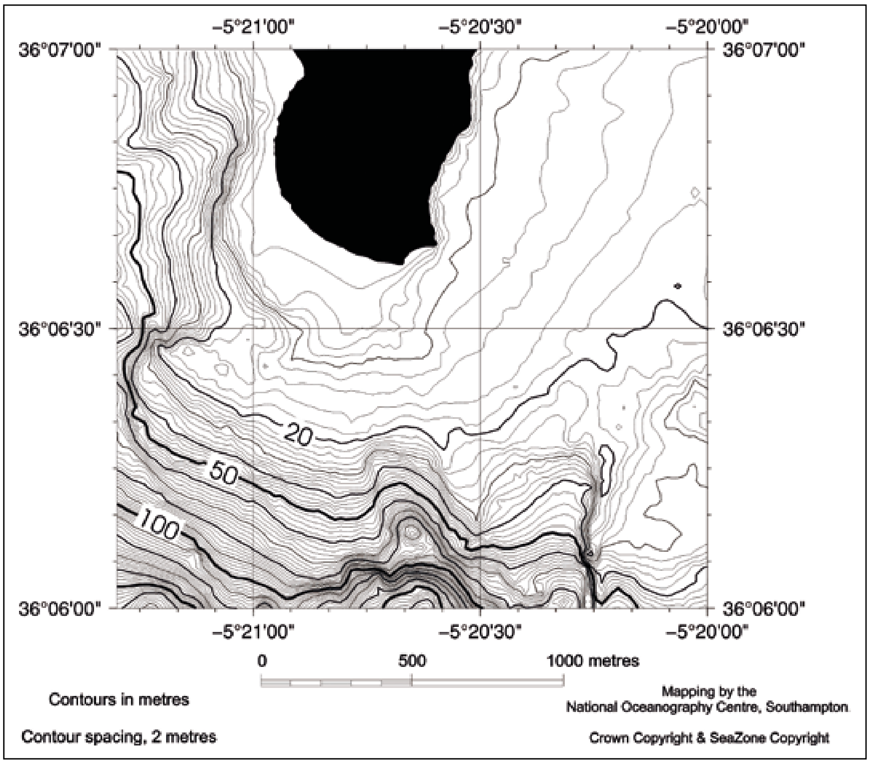


Fig. 5.6 Gibraltar, bathymetry showing submerged topography with cliffs which have caves in them.

The hydrodynamics of the Mediterranean Basin are controlled by the North Atlantic water inflow, a deep water highly saline outflow, and the wind regime and the climate of the surrounding land areas (Pinardi and Masetti, 2000). Climate variability is related to the position of the sea basin at the transition between high and low-latitude influences. During the last glacial, the Mediterranean was affected by North Atlantic rapid climate changes, including Dansgaard/Oeschger and Heinrich events (Rohling *et al.,* 1998; Cacho *et al.,* 2000, Sangiorgi *et al.,* 2003; Sierro *et al.,* 2005). The African monsoon also seems to have extended across the Mediterranean Basin at certain times, leading to increasing freshwater input, reducing deep-water ventilation and sapropel deposition (Tzedakis, 2007).

As seen in the northern European seas, sea-level changes during the Holocene are the result of eustatic, glacialhydroisostatic and tectonic factors. In the central Mediterranean during the Late Pleistocene and Holocene, coastal areas were strongly modified mainly by sea-level change and by the impact of human activity. This is particularly evident in Italy where coastal modification started in the first millennium BC (Pasquinucci *et al.,* 2004). Much of the Italian coast is undergoing erosion and coastal retreat. Vertical land movements have also played a significant part in shaping the Mediterranean coastline and, in areas where volcanoes are present (such as the eastern Tyrrhenian margin and the Sicily Channel), their activity has caused significant vertical movements that resulted in relatively rapid sea-level change. At the last glacial maximum, the sea level was 135m lower than the present, exposing large areas of the continental shelf.

Submerged river valleys on shelf areas represent the extension of continental drainage systems during times when the sea level was lower and the valleys were subaerially exposed. The palaeovalleys can be traced to 70-80m below sea level on parts of the Italian shelf. In limestone areas outcropping along the Mediterranean coast there are well developed karstic systems which were active during the Messinian salinity crisis, and the sea-level lowstands during glacial periods. There are known to be thousands of submerged caves along the Mediterranean coast although these are only partially studied (Alvisi *et al.,* 1994; Cicogna *et al.,* 2003). Other major areas of submerged karst are in the Balearic Islands, southern France, the eastern Adriatic coast, and Greece. Such coastal features are often associated with submarine freshwater springs. The detection of possible human relics in submerged caves has so far proved difficult. Analysis of more than 50 years of searching for prehistoric remains in submerged caves reveals that a combination of wave attack during inundation, roof falls, encrustation, cementation, steep narrow shelves, and difficult access produces a situation where the costs of searching for artefacts are very high, and the chances of discovery rather low (Flemming and Antonioli, in press). While terrestrial sediments have been found in some undersea caves, and many examples of speleothems, human artefacts have been very rare. A new assessment of these problems is required.

The continental shelf around most of the eastern Mediterranean is less than 15km wide and has numerous high cliffs, rock outcrops, drowned karst, and submerged pinnacles. Palaeogeographic models of the Eastern Mediterranean area have been presented by Lambeck (1995, 1996) and Lambeck and Purcell (2005, 2007). Active tectonic processes create a dynamic environment with long- and short-term, vertical and horizontal, crustal movements, which drive the evolution and continuous change of landscapes above and below the sea level, and are superimposed upon GIA sea-level fluctuations. Comparison of observations and field data, including different geomorphological and archaeological sea-level markers, with the predicted sea level curves, may provide estimates of the vertical tectonic contribution to relative sea-level change (Lambeck *et al.,* 2011).

The Aegean Region, including the Hellenic Arc, is the tectonically and kinematically most active area in Europe. Continuous, long-term, tectonic uplift and/or subsidence by 1m/kyr or more is evident at many places along the Hellenic Arc and within the Aegean Region, and has been documented with mapping and dating of uplifted Pleistocene marine terraces or submerged prodelta prograding sequences (e.g. Armijo *et al.,* 1996, Lykousis *et al.,* 2007; Lykousis, 2009). Short-term, incremental, vertical movements during the Late Holocene modify the modeled post-LGM sea-level rise (Lambeck and Purcell, 2007), as postulated by up to 6m or more uplifted or submerged palaeo-shorelines. These are observed in numerous places along the Aegean coastline like Crete, Rhodes, Gulf of Corinth, Euboea Island, the Aegean Islands etc. (e.g. Pirazzoli *et al.,* 1989, Kontogianni *et al.,* 2002, Evelpidou *et al.,* 2012a; 2012b). The most extreme event of abrupt, tectonic dislocation ever recorded in the Mediterranean Sea is associated with the 365AD, magnitude M>8 earthquake which occurred along the Hellenic Arc and uplifted Western Crete by up to 8m (Shaw *et al.,* 2008).

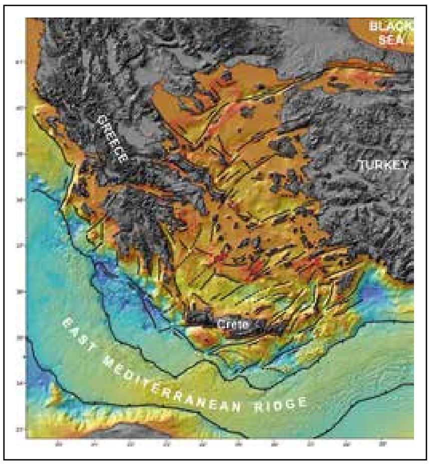


Fig. 5.7a Morphological-Bathymetric map of the Aegean Region extracted from the CGMW/UNESCO Morpho-Bathymetry of the Mediterranean Sea (Brossolo *et al.,* 2012). Major tectonic elements and fault network (black lines) and active volcanic centers (red dots) after Sakellariou *et al.* (2013).

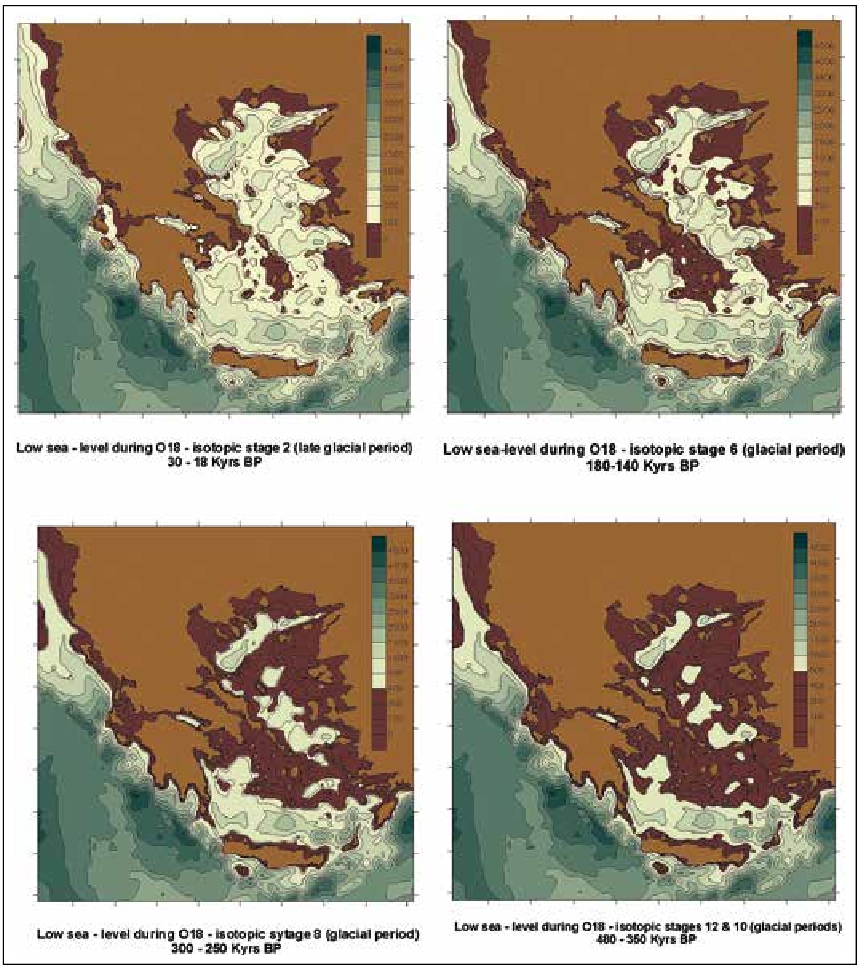


Fig. 5.7b Palaeogeographic reconstruction of the Aegean Region during major low sea-level stages of the last 500kyrs (Lykousis, 2009)

Crustal deformation in Central Greece has led to localized subsidence and the creation of deep basins below the Gulf of Corinth (870m depth), North Evia Gulf (450m depth), West Saronikos Gulf (400m depth) and other gulfs. All of these currently marine basins are connected to the open sea through narrow and shallow straits which were exposed land during the LGM and possibly during earlier glacial stages. Consequently, these water bodies were isolated lakes during the LGM and their water-level varied from the surrounding sea-level (Perissoratis *et al.,* 1993; Richter *et al.,* 1993; Lykousis and Anagnostou, 1994; Kapsimalis *et al.,* 2005; Lykousis *et al.,* 2007; Sakellariou *et al.,* 2007a; 2007b).

Due to the continuously evolving landscape, the geography of the Aegean Region in any given high or low sea-level stage has never persisted into the next stage (Lykousis, 2009). The interplay between periodically fluctuating sea level and long-term tectonic activity has led to the formation of extended landmasses during Pleistocene low sea-level stages, separated from each other by narrow sea-straits. The palaeogeographical configuration may represent areas where early seafaring has evolved.

The Sea of Marmara (SoM) is a gateway between the Mediterranean and the Black seas and is connected to these adjacent seas through the straits of Istanbul (Bosporus) and Çanakkale (Dardanelles) with sills at water depths of 35 and 65m respectively. Being strategically located between the world's largest permanently anoxic basin of the Black Sea and the Aegean Sea, the SoM is important for studying the chronology of palaeoclimatic and palaeoceanographic events related to glacial-interglacial cycles and continental shelf evolution in general. Important issues include the timing of water-mass exchanges between the Mediterranean and Black seas via the SoM and the water level changes (e.g., Çağatay *et al.,* 2000, 2009; Aksu *et al.,* 2002a,b).

The Sea of Marmara was essentially a brackish water lake until its reconnection to the marine environment at 14.5 ka BP (Vidal *et al.,* 2010). During the transition to the Last Glacial Maximum, the SoM reached its lowest level at around 105 m below present-day sea level (Smith *et al.,* 1995; Aksu *et al.,* 1999; 2002b; Çağatay *et al.,* 2003; Hiscott *et al.,* 2007; Eri *et al.,* 2007). The shelf areas of the SoM during this time were therefore subaerially exposed to a depth below the shelfbreak at about 90 m water depth (Smith *et al.,* 1995; Aksu *et al.,* 1999; 2002b; Çağatay *et al.,* 2003; Eris *et al.,* 2007). The onset of the last interglacial period, which was associated with a rapid global sea-level rise, led to the connection of the SoM with the Mediterranean Sea about 12,000 (e.g., Stanley and Blanpied, 1989; Çağatay *et al.,* 1999, 2000, 2003; Ryan *et al.,* 2003; Hiscott *et al.,* 2002a; Sperling *et al.,* 2003; Eriş *et al.,* 2007), or 14,700 years ago (Vidal *et al.,* 2010). There are archaeological findings distributed along the shores of the Sea of Marmara.

Black Sea

The Black Sea is the largest anoxic basin in the world with a maximum depth of about 2250m, an average depth of 1,240m, surface area of 4.2 x 10^5km^2 and a volume of 5.3 x 10^5km^3 (Özsoy and Ünlüata, 1997). The sea is about 1,000km in an east-west direction and 400km from the north to south. The shelf edge is located at about 100m water depth. The abyssal plain area (deeper than -2,000m) and shelf and uppermost slope area (shallower than 200m) are 60% and 25% of the entire sea area, respectively. The shelf area in the west and northwest is up to 150km wide due to the fan-delta complexes of the major European rivers (Danube, Dnepr, Dnestr), whereas it is less than 20km along the Anatolian and Caucasus coasts, where the continental slope is steep and intercepted by submarine canyons. The Black Sea is divided into Western and Eastern Black Sea basins by the Archangelsky-Androsov Ridge, which is a tectonic element extending from offshore Samsun on the Anatolian coast to the Kerch peninsula.

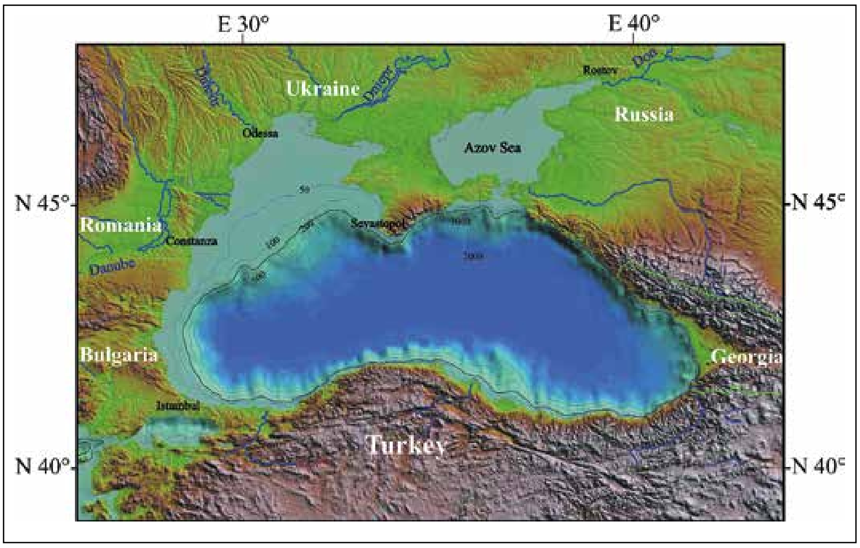


Fig. 5.8 Setting of the Black Sea, showing large rivers in its watershed

Credit: G. Lericolais

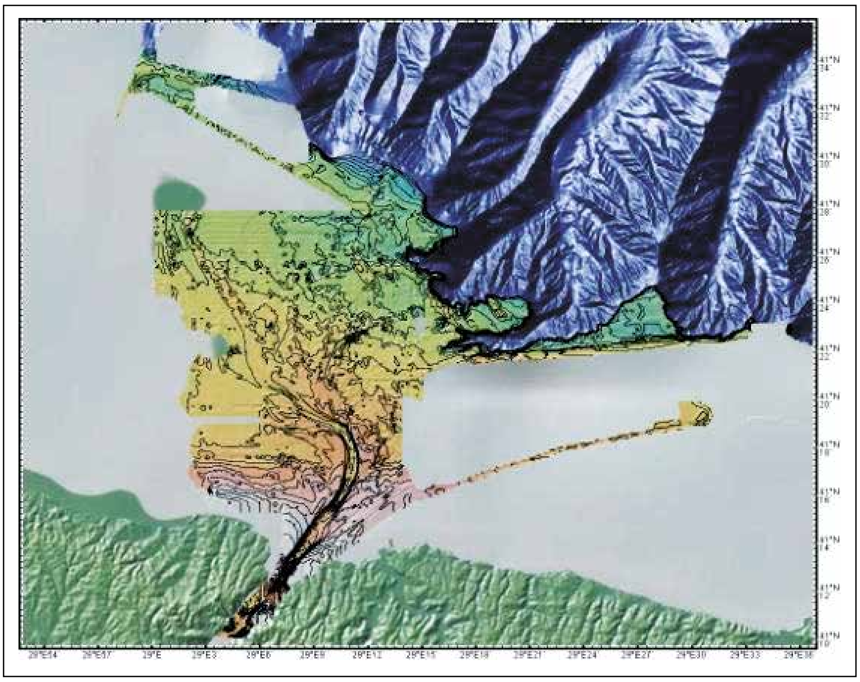


Fig. 5.9 Multibeam bathymetric map of the Istanbul Strait (Bosporus) outlet area (Okay *et al.,* 2011)

Sedimentary and geochemical analyses of sediment cores and morphological features observed on bathymetric maps and seismic sections provide evidence of sea-level, oceanographic and environmental changes in the Black Sea since the last glacial maximum. The shallow sill depth at the Bosporus Strait has interrupted the connection between the Black Sea and the world ocean during glacial lowstands, exposing substantial parts of shelf areas. During the last glacial epoch and deglaciation, the Black Sea was a freshwater lake with water levels varying between -80 and -120m. The latest seismic and core studies suggest that the Black Sea level was -120m or lower during the Last Glacial Maximum. According to core data (Bahr *et al.*, 2008), the sea was a stable freshwater lake until about 16.5 ka BP when melting ice sheets provided large amount of meltwaters to the basin.

The great floods caused by ice sheet and permafrost melting provided large amounts of water and sediment to the Black Sea via the European rivers and a greatly-expanded Caspian lake flooded the Black Sea via the Manych spillway (Ryan *et al.*, 2003; Tchepalyga, 2007; Ryan *et al.*, 2007; Lericolais *et al.*, 2007a&b, 2009, 2011). Muds transported by Dnepr and Dnestr were deposited on the floor of the Western Black Sea Basin.

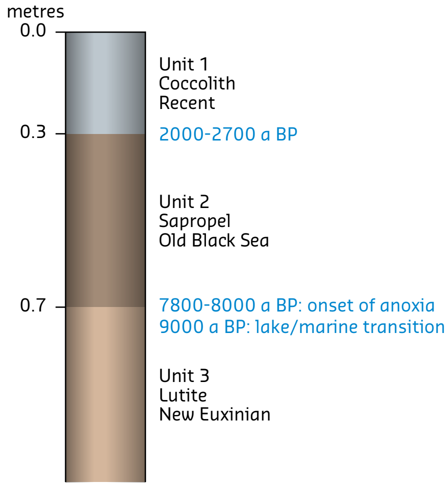
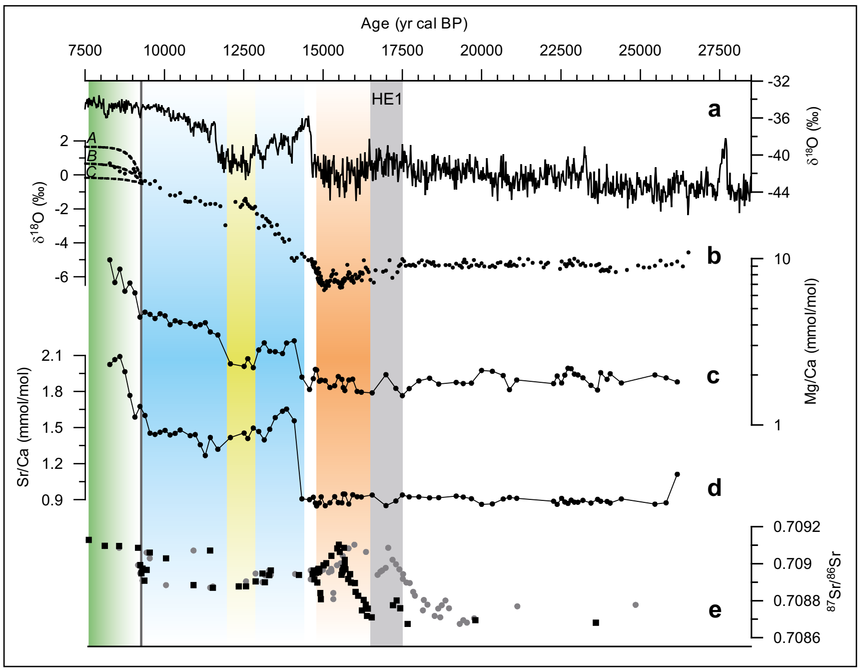


Fig. 5.10 Holocene to late Pleistocene stratigraphy of the Black Sea slope and abyssal plains showing various important events in the Holocene history of the basin (Çağatay, 1999).



Credit: After Bahr *et al.*, 2008

Fig. 5.11 Comparison of multi-proxy data from the Black Sea sediments (b-e) with Greenland ice core oxygen isotope record (a) covering the last glacial-early Holocene period (Bahr *et al.*, 2008). $\delta^{18}O$ (b), Mg/Ca (c), Sr/Ca (d) were measured on ostracod and $^{87}Sr/^{86}Sr$ (e) on ostracod and bivalve shells. Dashed lines in $\delta^{18}O$ graph (b) indicate the hypothetical evolution of Black Sea water for a maximum flux (5,475 km^3/a), a moderate flux (500 km^3/a), and a small inflow (80 km^3/a) of Mediterranean/ Marmara Sea water via the Bosporus into the Black Sea. Grey, red-brown, yellow and green bands represent Heinrich Event 1 (HE1), chocolate-brown clay (RL), Younger Dryas (YD) and sapropel (S) intervals. Blue stripes indicate the Bølling-Allerød (C3) and the earliest Holocene (C2) when relatively warm climatic conditions prevailed.

Seismic evidence suggests two postglacial lowstands; one shortly after the great meltdown (i.e. during the Bølling-Allerød; 15-13 ka BP) and the other after the Younger Dryas. The Younger Dryas (12.9-11.7 ka BP) was a period of lake transgression in the Black Sea, followed by a regression and then reconnection to the ocean.

Evidence of water level changes in the Black Sea 'lake' are also observed in the form of ancient shorelines, forced regressive sequences and continental sedimentary facies in western and north western shelf areas. The latest reconnection with the Mediterranean was established through the Bosporus at ca. 9 ka BP (Major *et al.,* 2002, 2006; Ryan *et al.,* 2007; Soulet *et al.,* 2010). However, whether the mode of reconnection was 'catastrophic' or 'gradual' is still a matter of debate. The catastrophic hypothesis claims that Mediterranean waters flooded the Black Sea "lake", with a low water level at -90 to -100m, and filled it within days or months (Ryan *et al.,* 2007). The alternative hypothesis favours the gradual marine inflow into a Black Sea "lake" with water level already at the Bosporus sill depth (e.g. Aksu *et al.,* 2002 and Hiscott *et al.,* 2007).

5.3 Data sources

Since 2008, data have been aggregated and compiled for the European Regional Seas under the European Commission's European Marine Observation and Data Network (EMODnet) Programme. The network consists of a consortium of organizations within Europe that assembles marine data, data products and metadata from diverse sources in a uniform way. The main purpose of EMODnet is to unlock fragmented and hidden marine data resources and to make these available to individuals and organizations (public and private), and to facilitate investment in sustainable coastal and offshore activities through improved access to quality-assured, standardized and harmonized marine data. EMODnet is an initiative from the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE) as part of its Marine Knowledge 2020 strategy[33]. There are seven sub-portals in operation that provide access to marine data from the following themes: bathymetry, geology, physics, chemistry, biology, and seabed habitats and human activities.

Bathymetry

The overall objectives of the EMODnet Bathymetry Project is to fill in the gaps of the EU's low-resolution bathymetry map and to assemble a complete inventory of high-resolution seabed mapping data held by public and private bodies. Working together with research institutes, monitoring authorities and Hydrographic Offices the project will collect hydrographic datasets and compile Digital Terrain Models (DTM) at a resolution of 0.25 by 0.25 minutes for each geographical region (Fig. 5.12). The DTMs are then loaded and integrated into a spatial database with powerful, high-end bathymetric data products viewing and downloading service that is complemented by Web Map Services (WMS) to serve users and to provide map layers to, for example, the other EMODnet portals, the prototype European Atlas of the Seas, and the broad-scale European Marine Habitats map. The portal includes a metadata discovery and access service that gives clear information about the hydrographic survey data used for the DTM, their access restrictions and distributors. The system also includes a mechanism for requesting access to basic measurements data.

[33] http://ec.europa.eu/maritimeaffairs/policy/marine_knowledge_2020/

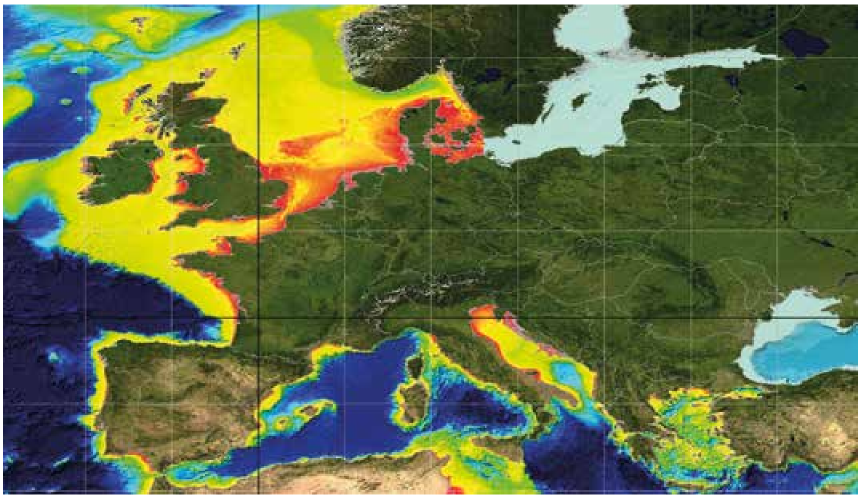


Fig. 5.12 Bathymetry of the European seas (EMODnet Bathymetry Project).

Other bathymetric data sources

Other international data resources include the International Hydrographic Organization (IHO), which co-ordinates the activities of national hydrographic offices[34]. The Baltic Sea Bathymetry Database (BSBD) is an effort to gather data in one place and distribute it for the areas of all Baltic Sea countries. This web site offers complete, homogeneous and up-to-date Baltic Sea bathymetry data from "official" sources: All Baltic Sea national hydrographic offices under the umbrella of the Baltic Sea Hydrographic Commission. The BSBD project is co-financed by the European Union Trans-European Transport Network (TEN-T)[35] and provides a digitized topography of the Baltic Sea[36]. Land heights and water depths have been calculated for two regular spherical grids from available data.

The International Bathymetric Chart of the Mediterranean (IBCM) is an intergovernmental project to produce regional-scale bathymetric maps and data sets, together with geological/ geophysical overlays, of the Mediterranean Region including the Black Sea. Sponsorship of the IBCM project comes from the Intergovernmental Oceanographic Commission (IOC) of UNESCO. The International Hydrographic Organization (IHO) also maintains a strong interest in the project.

[34] http://iho.int/srv1/

[35] http://data.bshc.pro/#2/58.6/16.2

[36] http://www.io-warnemuende.de/topography-of-the-baltic-sea.html

Substrate and Quaternary geology

The EMODnet-Geology portal is constructed by a group of national geological survey organizations to provide access to data and metadata held by each organization. The data and map products include information on the sea-bed substrate including rate of accumulation of recent sediments; the sea-floor geology (bedrock and Quaternary geology) and all boundaries and faults that can be represented at a compilation scale of 1:250,000 wherever possible. An index map showing the scale at which each country has compiled geological maps is shown in Fig. 5.13. The map is a useful indicator of areas where further work is required to provide archaeologists and other users of geological information with the detailed interpretations that are required to assist their work.

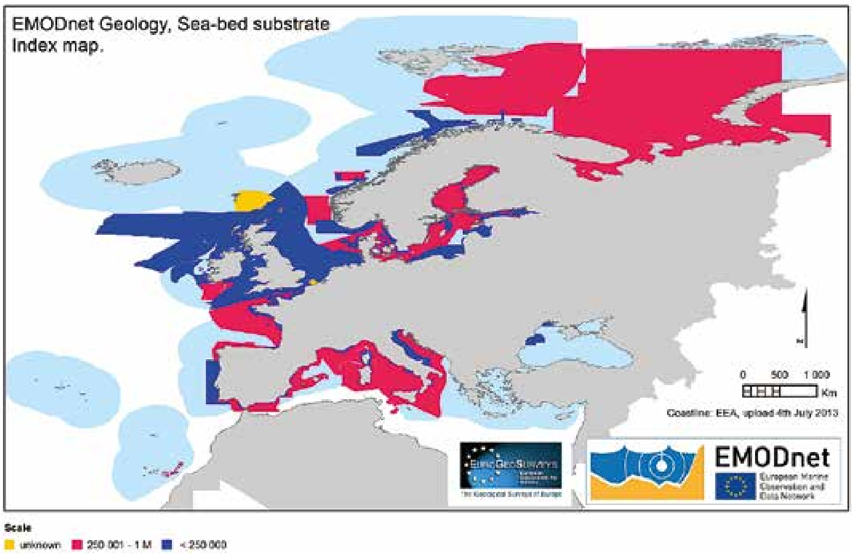


Fig. 5.13 Index of geological maps available for the European seas and the scales at which the maps have been compiled. The map shows that large areas of the seafloor geology are interpreted at a scale of less than 1:250,000 with the exception of the coastal zone of the southern Baltic Sea, the northern coast of Norway, the North Sea and Celtic Sea, offshore Portugal, and parts of the Italian coast and Black Sea.

The portal also includes information on the lithology and age of each geological unit at the seabed; geological events and probabilities, and minerals. For the coast, information on coastal type and behaviour will be supplemented by information on coastal erosion or sedimentation and the rate at which it occurs. All of the interpreted information is based on primary information owned by the project partners, supplemented with other information that is available in the public domain.

A map of available offshore Quaternary geology information is being compiled using data held by the geological survey organizations of Europe. The proposed map and supporting information will include the age, lithology, genesis, geomorphology, and information about the Quaternary geology at the time of the Last Glacial Maximum where possible. The work will link to the IQuaME 2500 project (see final section of this chapter).

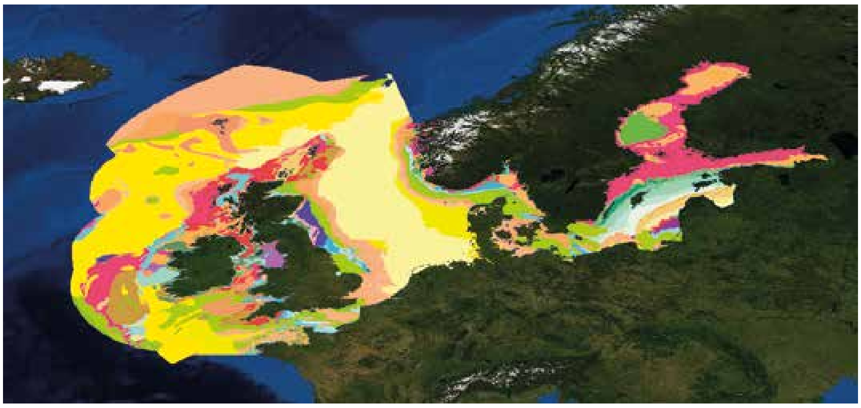


Fig. 5.14 Example of bedrock stratigraphy map for northern Europe (EMODnet-Geology Project)

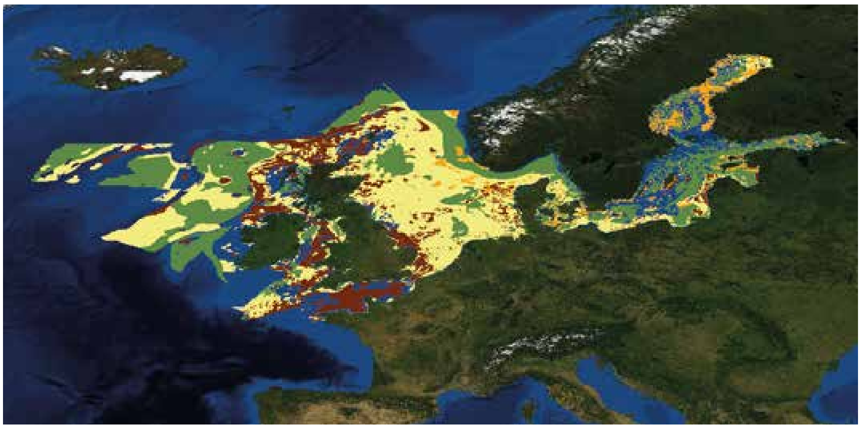


Fig. 5.15 Example of seabed sediments map for northern Europe (EMODnet-Geology Project)

Coastal behavior and erosion

The EMODnet-Geology Project aims to classify all coastal types in each country at 1:250,000 scale including information on rates of sedimentation and erosion. The central parameter in the final description of coastal behaviour is the rate of shore normal coastline migration. The starting point for information compilation is the EUROSION database supplemented by data held by the EMODnet partners and sources such as 'Coastal Erosion and Protection in Europe' (Pranzini and Williams, 2013) which includes information on Europe's coast on a country-by-country basis.

An EC-funded EUROSION project (2002-2004) integrated natural and human-induced causes of erosion (storms, seismic movements, reduced sediment supply from rivers due to dams, coastal defences etc.); different uses of both the terrestrial and marine environments of the coast, ranging from biodiversity and landscape conservation to tourism, industry and transport; and the different levels of management from the local level up to European and regional sea management. Through supporting the Integrated Coastal Zone Management Practitioners Network and facilitating access to relevant data and information, EUROSION offers a follow-up to the EU demonstration program on Integrated Coastal Zone Management, with an emphasis on pilot projects which focused on erosion management, and is consequently biased towards ICZM strategies.

Quaternary palaeo-environments

The International Union for Quaternary Science (INQUA) was established in 1928 and exists to encourage and facilitate the research of Quaternary scientists in all disciplines. Five commissions, coastal and marine processes; humans and biosphere; palaeoclimates; stratigraphy and chronology; terrestrial processes, deposits and History, provide leadership in different spheres of research, and are responsible for ensuring that INQUA scientists remain at the forefront of their fields. INQUA currently funds projects of relevance to marine archaeology under each theme.

These include:

- MEDFLOOD[37]: MEDiterranean sea level change and projection for future FLOODing.
- PALSEA2[38]: PALeo-constraints on SEA-level rise 2
- Humans and biosphere: Modelling human settlement, fauna and flora dynamics in Europe during the Mid-Pleistocene Revolution (1.2 to 0.4 Ma).
- Cultural and palaeoenvironmental changes in Late Glacial to Middle Holocene Europe: gradual or sudden?
- DIG – 1st Workshop on DInaric Glaciation: Early/Middle Pleistocene glaciations of NE Mediterranean
- SEQS (Section on European Quaternary Stratigraphy) Framing European Quaternary Stratigraphy
- UNESCO-IUGS-IGCP521-INQUA501 WG12. Black-Sea Mediterranean corridor during the last 30ky: sea level change and human adaptation

The IQUAME 2500 Project, a joint initiative of the CGMW/INQUA/BGR to the International Quaternary Map of Europe, links the EMODnet-Geology Project group through common partners to provide marine information This will develop a baseline of Quaternary geology map of both the land and marine areas of Europe. The projects will compile information of the age, lithology and genesis of Quaternary deposits as well information on glacal maxima.

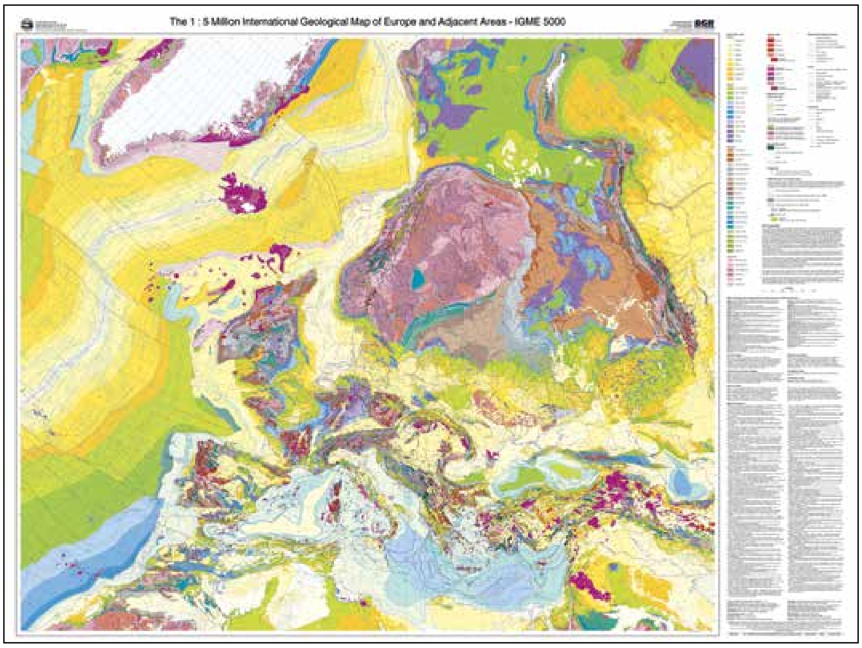


Fig. 5.16 The International Quaternary Map of Europe (1:5,000,000). The EMODnet-Geology Project aims to compile the offshore component of the Quaternary map of Europe by 2016.

Credit: Asch, K. (2005) IGME 5000 1:5 Million International Geological Map of Europe and Adjacent Areas, final version for the internet. BGR, Hannover

[37]http://www.medflood.org/

[38]http://people.oregonstate.edu/~carlsand/PALSEA2/Home.html

SUMMARY

Geological mapping of the European seas exists at various scales across the continent. Efforts to compile the available information at a pan-European level are in progress in programmes such as the European Commission's European Marine Observation and Data Network (EMODnet). There is a need for detailed seabed and sub-seabed mapping using high-resolution information provided by for example by multibeam echosounder systems. National mapping projects such as the Norwegian MAREANO Project, the Irish INFOMAR project and the UK Marine Environmental Mapping Programme are delivering more detailed maps of the offshore geology. In terms of palaeolandscapes, there is a particular need for more detailed Quaternary geology maps at the highest resolution possible using the available data.

The EMODnet Programme has been successful in bringing together various science communities to identify the data that exist at a European level. The programme would benefit from input from the marine archaeological community to not only deliver an assessment of the status of palaeolandscape understanding, but also to communicate their specific requirements from the other EMODnet projects, especially the bathymetry and geology components of EMODnet.

Given the great range of differences between the various European sea basins, and the different evolution of the seabed and sedimentary structures, the researchers studying the prehistoric occupation of the continental shelf need access to specialized regional and local data at high resolution.

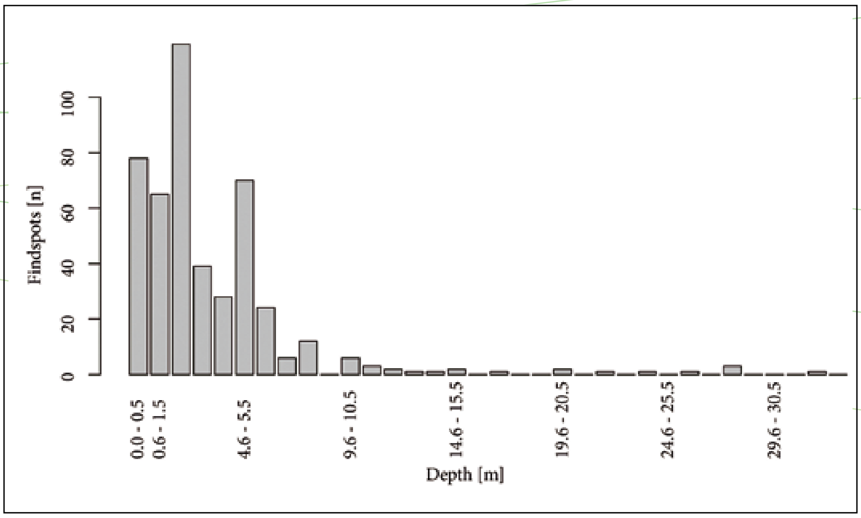
6

Research technology: Challenges and opportunities

Credit: Pavlopetri Project

A wide range of techniques for underwater exploration are available for scientific, military and industrial purposes. Access to these techonolgies has been restricted by their cost and fast evolution. An optimum method to apply new technology more effectively in Continental Shelf Prehistoric Research is often lacking. New developments are needed to 'tune' the existing techniques to specific scientific targets, as they were often developed for other purposes. Modification (or implementation) of existing technologies is probably at present the best possible way for submerged archaeological and palaeolandscapes studies, as there is still not enough industrial/economic/scientific pressure to develop specific prospection tools. Once there is high probability or proof of a preserved site, further specialist techniques are needed for site survey, assessment, and preservation/ excavation.

The majority of known submerged prehistoric landscapes and sites were found in shallow waters (<10 m), often with good visibility and accessibility (Fig. 6.1). A small but significant number of sites have been examined in the depth range of 10-50m. However, large number of well-preserved sites and landscapes in deeper waters (10-150m) remain largely unexplored despite they can provide crucial information of human adaptation history during the first postglacial millenniums, when there was a permanent shoreline displacement and rapid inundation of the habitats of humans and mammals caused by fast sea level rise (2m/century). Direct evidence of human presence within these landscapes is difficult to obtain primarily due to the water depth but also to the less favourable conditions such as strong current, silting and low or zero visibility. Interdisciplinary cooperation between archaeology, science and engineering is required to explore the vast archive of deep water domains.



Source: SPLASHCOS

Fig. 6.1 Number of known submerged prehistoric sites versus water depth. It is clear from this graph that majority of the sites reported so far are located in very shallow water.

Researchers deploy Kongsberg Mesotech sector-scanning sonar to investigate submerged ruins.

6.1 Technology for underwater prehistoric research

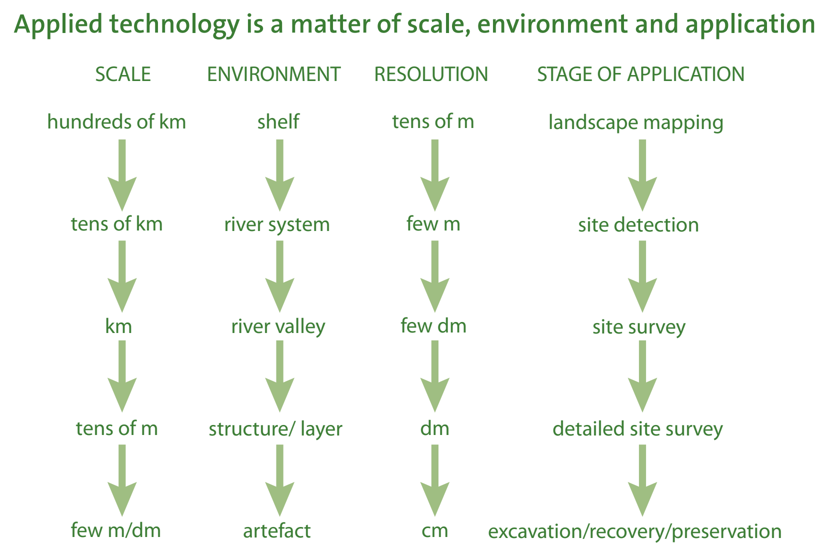
Two major challenges in technology for Continental Shelf Prehistoric Research are the varying scale and environment. The size of surveying area determines the exploration approach and resolution required, for example, from searching large palaeolandscapes in wide areas of the continental shelf to small (buried) structures of a few square metres. The detection and identification of increasingly smaller objects requires further high resolution and is pushing technology to the limit.

Similarly, natural environment influences the technology used. Exposed or buried features, deep or shallow water, sandy or rocky seafloor, hard or soft sediments will in most cases require different technologies. Cave sites are particularly susceptible to this issue. Thousands of caves have been found in the submerged limestone karstic environments of the Mediterranean (See Chapter 5) but it is very difficult to survey accurately their 3D morphology, and even more difficult to detect prehistoric remains, if they exist, in the assemblage of roof-falls, rock debris, terrestrial soils, speleothems, and modern marine sediments and encrustations. The nature of the topography (inclined walls instead of a more or less horizontal surface) poses major challenges to every available technology(acoustic, electromagnetic or photographic imaging). The local environmental conditions such as currents, waves, sedimentation, and, especially, visibility will affect the techniques that are used. Direct archaeological investigations at shallow sites with good visibility and accessibility may be done with similar excavation and data recording techniques as on land – if one ignores the fact that the excavators needs to have diver's gear and that a suction spout is a more important tool than a trowel or a spade. In contrast, underwater excavations, documentation and sampling in water deeper than 10-120 m with poor visibility will require extremely specialized techniques.

Closely related to scale, the 'stage of application' will determine the technology to be used, from largescale but low-resolution landscape mapping to small-scale but high-resolution site imaging, including sampling, excavation, artefact recovery, site stabilization, documentation, visualization, core interpretation, and site preservation or backfilling. Different technologies are applied in different phases of a survey, for example: (a) commercial seismic data for a rough reconstruction of the submerged landscapes (e.g. river systems and shorelines); (b) side scan sonar or multibeam echo sounder to register seafloor features (e.g. preserved tree stumps and fallen trunks exposed on the bottom); (c) 2D or 3D high-resolution subbottom profilers to detect archaeological features or small terrain anomalies embedded in the bottom; (d) van Veen samplers and box corers to recover samples of the seafloor and sub-seafloor.

Due to the large variety in scale, environment and application stage, the range of techniques and methods applied in Continental Shelf Prehistoric Research is very wide, from remote sensing, Lidar and (electro-)magnetic techniques, to direct investigations such as coring, sampling and excavation, 2D/3D photography, remotely operated vehicles, and numerical modeling.

BOX 6.1. Range of scale, environment and application stage in submerged archaeological studies



Over the last decades enormous technical progress has been made in geophysical recording and documentation methods that are able to provide high resolution data about the sediments and structures on and in the seafloor. Some remote sensing technologies have originally been designed and developed for other research applications, such as mine detection and shipwreck studies, but they can be effectively applied (if needed with slight adaptation) to submerged prehistoric studies. Notwithstanding this technological progress the identification of artefacts or other physical evidence of a prehistoric site by remote sensing remains a huge challenge, particularly in the case when the artefacts are buried below the seafloor (Grøn *et al.,* 2013 and Hermand *et al.,* 2011).

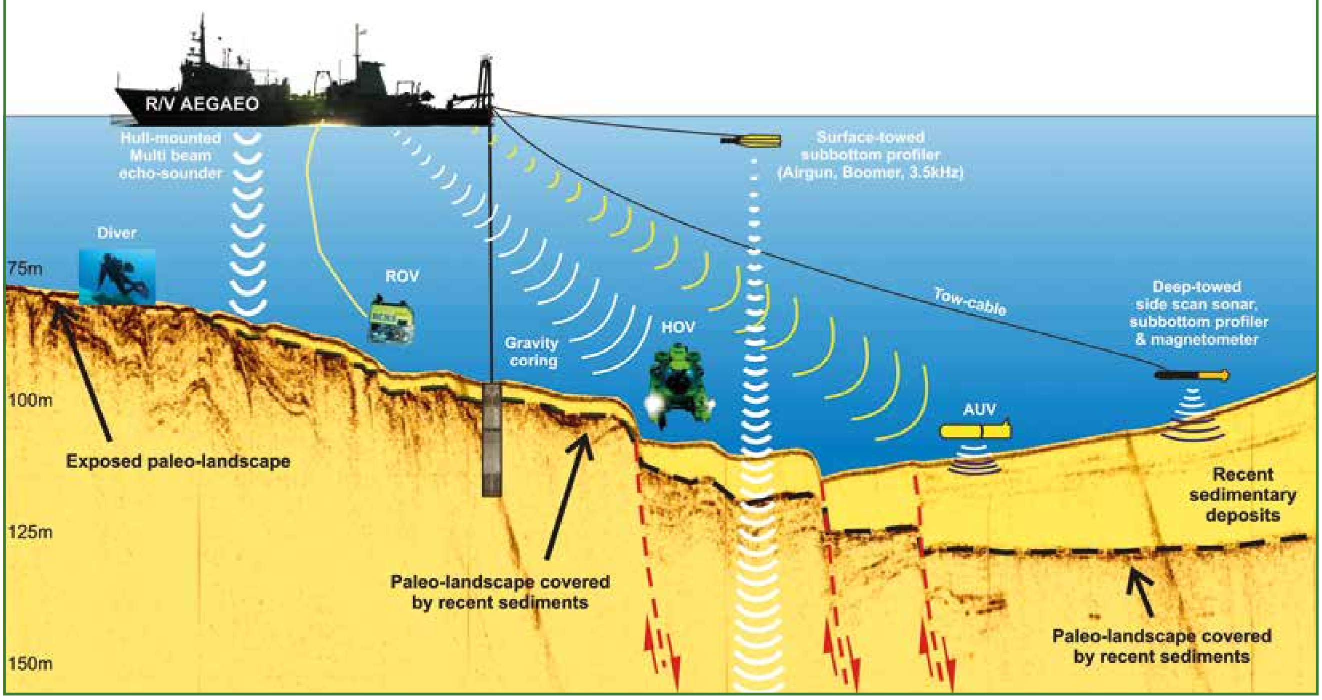
Geophysical recording therefore always needs to be complemented with genuine archaeological investigations. In recent years direct observation methods with regard to documentation, sampling, excavation and preservation of cultural deposits have become increasingly efficient, especially in relatively shallow water environments. However the major challenge lies in the development of specialized techniques for archaeological investigations in deeper water (10-120m), and/or environments with poor or no visibility.

Dating is an important factor in archaeological and palaeolandscape studies. There are a number of available methods depending on the nature of the indicator in question. Frequently used methods include radiocarbon dating: conventional 14C and the newer AMS (Accelerated Mass Spectrometry), uranium-series dating, optical stimulated luminescence (OSL) dating, tephrachronology and dendrochronology. New developments are under way in OSL dating of (reworked) marine sediments, which should lead to more reliable age estimations.

BOX 6.2

(a) Simplified diagram showing technologies involved in submerged prehistoric research. (b) Illustration of a number of seabed and sub-seabed remote sensing and intervention technologies. The research ship is operating above a partly buried palaeo-landscape marked by faults and locally complex internal bedding. Coring can sample the sediments whereas acoustic sensors image the seabed and substratum, while divers and towed/propelled vehicles can make observations, or conduct mechanical work.

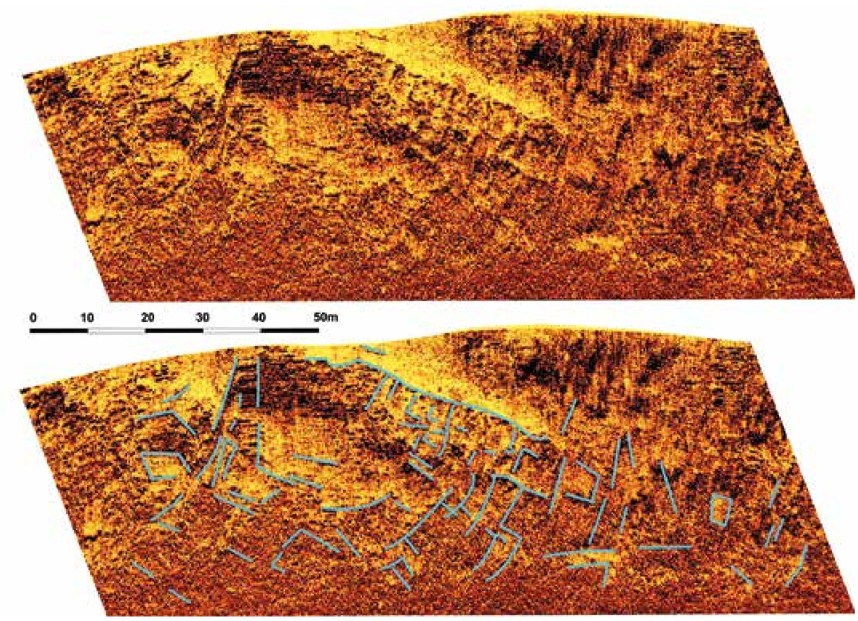
METHOD	TECHNIQUE	TYPE OF DATA	TECHNOLOGY
REMOTE SENSING	Acoustic	Seafloor map	Side scan sonar, multibeam echosounder
	Acoustic	Sub-seafloor image (2D) Sub-seafloor image (3D)	Sub-bottom profilers 3D Chirp, SES-2000 Quattro
	Lidar (Electro-)magnetic	Seafloor topography Seafloor and sub-seafloor magnetic/resistivity map	Airborne Lidar Bathymetry EM profilers, gradiometers
DIRECT INVESTIGATION	Coring and sampling	Sedimentological/environmental	Grabs (van Veen, Shipek) Boxcore, vibrocore, gravity core, piston core
	Dive surveys	Sedimentological/archaeological	Swim dive (corridor/jackstay/circular)
UNDERWATER PLATFORMS	Submersibles (manned/unmanned)	Wide spectrum of data (acoustic maps, water/sediment samples, cores, video etc.)	HOV, ROV, AUV
PHOTOGRAPHIC	Photo, video, stereo	Exposed seafloor	Digital 2D/3D cameras, photo/video-mosaicing, video microscope

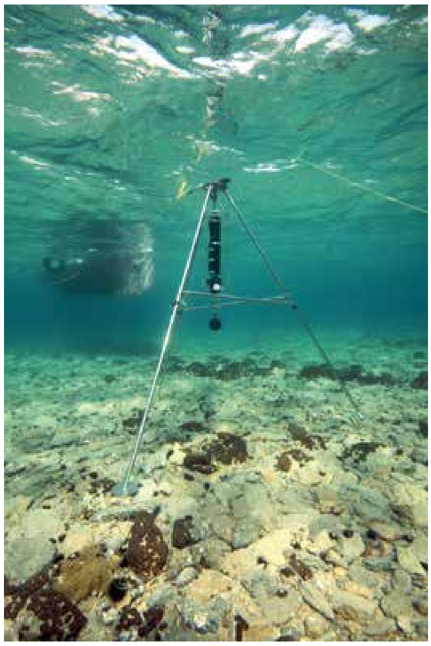


Credit: D.Sakellariou/ HCMR

Acoustic seafloor mapping

Where palaeolandscape areas are exposed or buried shallowly, side-scan sonar and multibeam echo sounders are very powerful tools because they provide detailed 'acoustic maps' of the sea bed. The main advantage of these techniques is that a large area can be scanned relatively fast (on average a few hours for a few square km) and with a high precision (decimetre to metre-range resolution). Over the years side scan and multibeam systems have been improving towards increasingly higher resolutions, in some cases up to cm-range resolution. This has resulted in an ever finer image of the seafloor morphology, its texture and sediments, and any objects or structures on the seafloor. However, there still tends to be a reduction in resolution with systems operating over longer range or wider swaths, while in shallow water, the swath width is inevitably reduced, and hence more tracks are needed. The continuous advance in materials has moreover resulted in highly compact systems that can be deployed on very small boats and in increasingly shallow water (down to a few metres). Though much improvement has recently been made in the identification of artefacts by smart combination of backscatter and bathymetry (Bates *et al.,* 2011), being able to distinguish anthropogenic features from natural phenomena remains very difficult.





Credit: Pavlopetri Project

Fig. 6.2 Side scan sonar image (400 kHz), obtained in 2-4 m water depth of the submerged prehistoric city of Pavlopetri in Greece. Blue lines highlight the remains of the walls of the buildings and roads. (Sakellariou et al, 2011) The image on the right shows a sector-scanner (Kongsberg MS1000) mounted on a tripod, and deployed in the centre of the ruins at Pavlopetri. The sector scanner projects sound at 750 kHz, and rotates in the tripod to build up a radial picture.

Recently a new generation of compact, high resolution imaging sonars known as 'acoustic cameras' has been developed for engineering purposes, such as pipeline inspection. These sonar cameras, often mounted on AUVs and ROVs, offer a 3D field-of-view (up to 130°) of the seabed and are especially useful in low or zero visibility conditions (Johnson-Robertson *et al.,* 2010). Another noteworthy development concerns multibeam echo sounder systems with vertical angular adjustment (by the use of a tilt motor), which can provide accurate images of inclined (even vertical) surfaces. This technique offers a huge potential for cave research.

Acoustic sub-seafloor mapping

Seismic remote sensing (also sub-bottom profiling) is used to image the palaeolandscape buried beneath the seafloor and possible archaeological remnants buried under the sand, mud and silt seabed substrate. This technique involves a wide range of seismic sources (e.g. boomer, sparker, chirp, and echosounder) and receivers (streamers, often with multiple hydrophones). Over the past decades, these techniques have yielded improved resolution ranging between 20 cm and 1-2m, but their full potential for submerged prehistory research is not yet well exploited. Ongoing studies in Belgium have demonstrated that a smart combination of sources, receivers and resourceful data processing, can improve the performance of subbottom profiling for archaeological studies.

Seismic investigations target features with relief, such as buried palaeochannel and associated terrace systems, shell midden accumulations, and organic deposits (e.g. peat layers). The latter are good indicators of past coastlines with high preservation potential. However, the identification of subsurface layers containing archaeological material remains problematic. Different features, for instance hard layers or fine-grained deposits, may sometimes yield a similar reflectivity and can be mistaken or confused. Moreover small buried features or artefacts are extremely difficult to identify with seismic remote sensing.

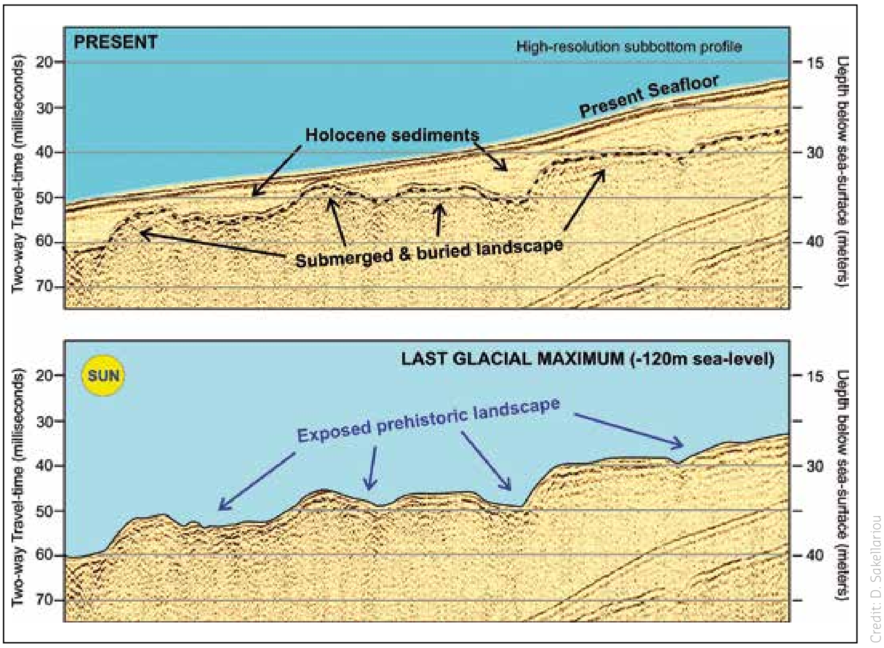


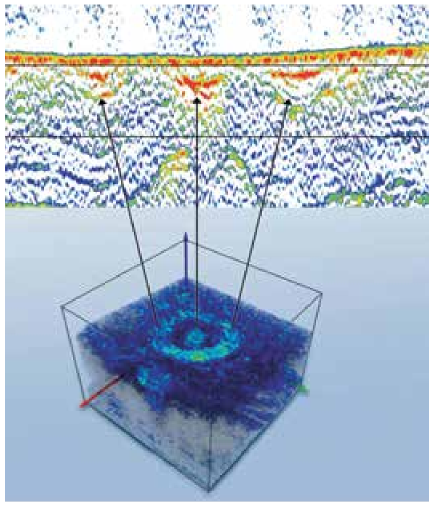
Fig. 6.3 Example of an acoustic subbottom profile showing the present sea floor and underlying buried landscape (top) and the original landscape when it was exposed during the last glacial maximum (bottom).

Conventional seismic profiling provides 2D data and through data interpolation with multiple streamers a 3D image of the sub-seafloor can be constructed that allows adequate imaging of large-scale topographical features (e.g. tens to hundreds of metres in size) but it will easily miss small features or artefacts of metre and sub-metre scale. The latter require true 3D imaging techniques. In recent years two unique acoustic systems were developed in the UK (3DChirp) and Germany (SES-2000 Quattro) that allow true 3D imaging of small buried structures with dm-scale horizontal and vertical resolution. Promising results were obtained for buried engineering structures and archaeological wooden artefacts (Gutowski *et al.*, 2008; Lowag, 2010).

Non-acoustic mapping techniques

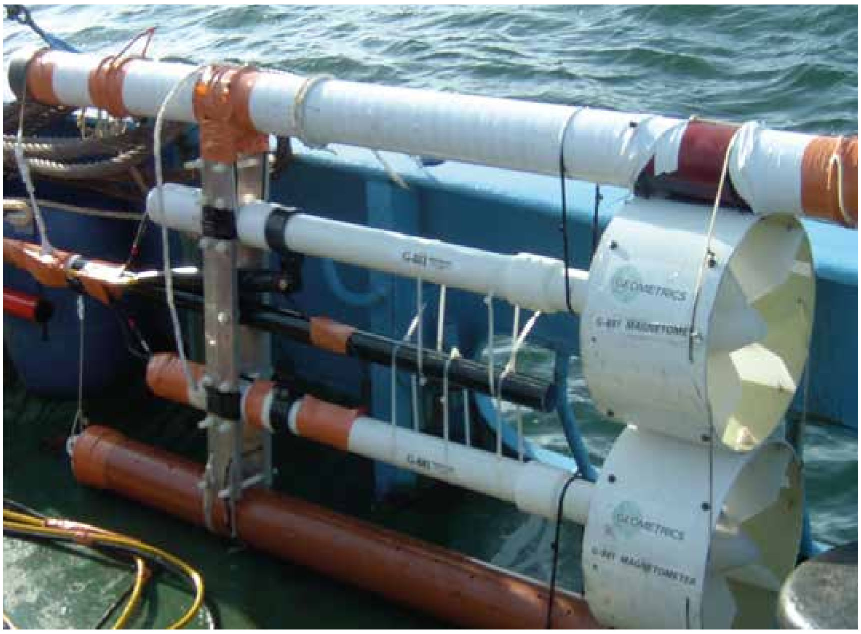
Less frequently used than acoustic methods, magnetic (or gradiometric) and electromagnetic (EM) techniques may be valuable tools to image the (sub)seafloor, especially when the sediments or archaeological remnants have a magnetic imprint and cannot be detected using acoustic methods (e.g. small ferrous objects, pit hearth/oven). Since the level of detail obtained with these techniques will decrease rapidly with the distance to the sensor, it is crucial to tow the equipment close to the seafloor.

Over recent years gradiometric and electromagnetic techniques have evolved considerably through the use of increasingly sensitive sources and sensors (Klein *et al.,* 2005, Missiaen and Feller, 2009). However, they are mainly used in shipwreck studies, and there is a lack of effective application to submerged prehistoric research. The recent development of a marine EM profiler ("GEM-Shark") in Germany opens new perspectives for archaeological studies (Muller *et al.,* 2009). At the same time, increasingly high-performance magnetometers are being used for the identification of submerged archaeological sites (Camidge *et al.,* 2010, Boyce *et al.,* 2004).



Credit: Innomar

Fig. 6.4 Acoustic subbottom image in 2D (top) and 3D (bottom) of a circular buried structure in Wismar Bay, Germany. Dimension of the 3D volume is 40x40x3m. Data obtained with the new 3D parametric echosounder system SES-2000 quattro.



Credit: G-Tec S.A.

Fig. 6.5 Marine magnetometer array used for highly detailed magnetic studies of the subseafloor. The array is towed close to the seafloor for maximum resolution.

Archaeological exploration using remote sensing techniques at nearshore and intertidal areas remains problematic due to the extreme shallow water (0-2 m), tidal effects and wave disturbance, despite being areas known to be rich in archaeological remains. Airborne LiDAR (Light Detection and Ranging) Bathymetry techniques (ALB) may provide a solution, a fast-developped remote sensing technology for 3D mapping (Pe'eri *et al.,* 2011) with comparable data quality to multibeam (Pastol, 2011). Important benefits of this technology are the ability to survey seamlessly across the land-sea boundary, and to map extremely shallow areas with complex and irregular topography that are off-limits and sometimes dangerous to conventional bathymetric acquisition techniques. Especially in retreating coasts where major storms may result in short exposure of lagoon or backshore environments before they are buried again or wiped out by waves, the availability of shallow water remote sensing tools will be crucial.

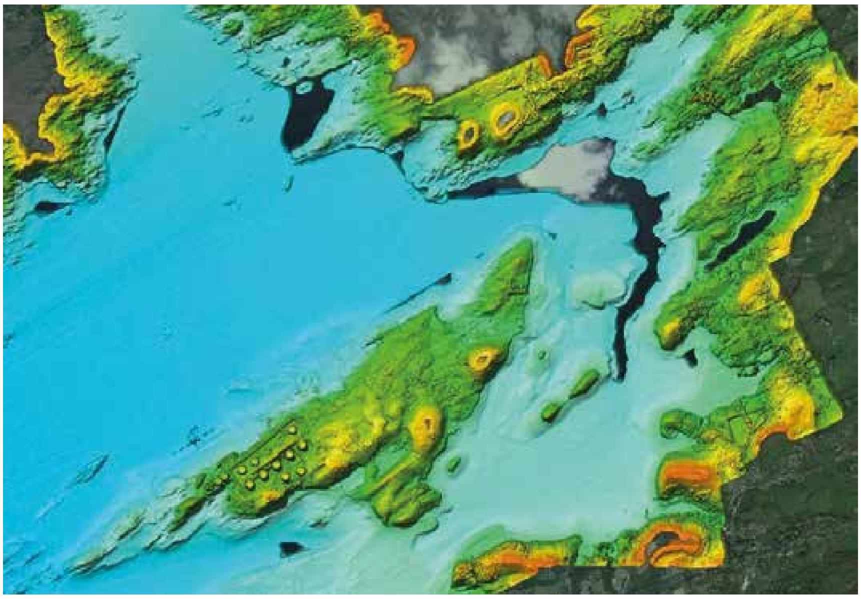


Fig. 6.6 Seamless integration of offshore multibeam data and terrestrial/intertidal LiDAR bathymetry data in Bantry Bay, Ireland, superimposed in Google Earth.

Credit: INSS/INFOMAR

Sampling, coring and excavation

In order to ground-truth the remote sensing data, samples of the seabed and sub-seabed are necessary. This can be done from boats by grab samplers and coring devices, or underwater by divers. By studying how the sediments, and the fossils within them, change over time, a picture emerges of how the landscape, climate and sea-level have fluctuated in the past. In general, increasing the amount of sampled, cored or excavated sediment will also increase the likelihood of prehistoric site discovery.

Grabs are easy to deploy and can give a very large sample, but they only provide information about the seabed near-surface. Corers on the other hand allow a cross section to a depth which theoretically can reach several tens of metres beneath the seabed, but in reality, rarely exceeds 10 m. Box corers can recover large undisturbed samples and the uppermost sedimentary deposits up to a few tens of decimetres below the seafloor. Most corers are limited in diameter (roughly 10 cm) and require powerful winches for their deployment and recovery. They are therefore mostly used by purpose-built oceanographic or geotechnical vessels, not easily accessible to the scientific community. Moreover cores or grabs cannot be obtained in rocky substrates.

Very shallow coring can also be carried out by divers. The primary reason for this is to sample palaeoenvironmental or archaeological horizons within a given sedimentary sequence and very precise location in relation to known cultural features. Borers or augurs up to 10cm thick can be used although the length of the core collected by the diver will depend on the nature of the deposit. The time a diver can spend underwater collecting a core will depend on the depth and the composition of the breathing gas. (See Box 6.3 on scientific diving).

Diver-controlled excavation involves the careful removal of sediment in order to expose archaeological layers and artefacts so they can be carefully recorded. Excavation often involves the use of hydraulic and airlift dredges. Whereas the latter performs better at greater depths, the former is very effective in shallow water (Faught, 2014). The dredged material can be sieved to recover any artefacts. When dealing with very small artefacts (e.g. prehistoric flints) it can be appropriate to recover material in sample boxes. In the case of loose deposits coffer structures are necessary for deeper excavations to prevent slumping of the sides. Rigid frames may furthermore be used to provide fixed points from which to measure or as support for divers to help them keep clear of delicate material.

So far surprisingly little research has been done to identify the sedimentary signatures of the deposits that make up submerged archaeological sites, despite evidence demonstrating that a detailed recording of colour, bedding, and contact descriptions complemented with point counting, grain size analysis and multiple geochemical analyses may allow experts to distinguish probable archaeological sites from natural sites (Gagliano *et al.,* 1982).

Credit: M. Gull

Fig. 6.7 Divers excavating the Mesolithic pit dwelling at Møllegabet II, Denmark, from a wooden platform positioned above the cultural layer under excavation.

Survey or excavation by divers

Underwater surveys by divers are conducted to record varying levels of detail on the seafloor, the level of detail depending on the method used. The latter may range from drift or contour dives, used to locate the position of anomalies, to planning frame surveys which can record an area in detail to a scale of 1:1. Plans produced by divers will often be complemented by photographs taken with underwater cameras. In general detailed underwater surveying and close-up mapping represents a critical stage of work, which leads to the decision as to how to handle a site: abandonment, map and forget, conduct some test pits or cores, or fully excavate or preserve.

Swim dives (swimming along a set path and visually recording anything seen on the seabed) can be carried out in predetermined survey areas. Common methods for comprehensive inspection of the seafloor are 'Corridor searches' and 'Jackstay searches'. Here, divers inspect the seabed along baselines laid on the seabed. Any archaeological features identified can be recorded on a prepared underwater slate. In a circular search, divers swim in a circle around a fixed point. For highly detailed surveys which are commonly to a scale of 1:20 but can be to 1:10 or even 1:1, survey grids are set up on the seabed and planning frames are used.

The resolution of the data varies greatly between the survey methods. For drift or contour dive, the position is less accurate as the movements of the divers are recorded intermittently (either from a cover boat following a buoy towed by the diver or recorded continuously by the diver if they have a GPS attached to the buoy). When working within a survey grid set up on the seafloor the accuracy of positions will be within a few centimetres. The underwater grid can be georeferenced with acoustic systems or positioned within a pre-established geo-acoustic framework.

Credit: E. Galili

Fig. 6.8 Divers excavating a fresh-water well on the seabed in a Neolithic village at Atlit, off the Israel coast. The sides of the well have been stabilized with sand-bags in order to provide an archaeological stratigraphic record.

Submersibles and underwater vehicles

Manned underwater submersibles (or human operated vehicles, HOVs) and remotely operated vehicles (ROVs) have been used by marine scientistists, military and offshore industry for over 40 years. One of the first underwater archaeological expeditions using a manned submersible involved shipwrecks off the coast of Turkey in the early 1960's (Bass, 1968). In 1989, the Jason ROV was used to work on a number of Roman shipwrecks off the coast of Sicily (Ballard, 1993) and set new technical standards for the depth involved. The Roman wrecks at a depth of 800m off the Skerki Bank were first observed during military surveys using the US Navy small nuclear-powered submarine NR1. Having observed the wrecks, a later project using the deep intervention Jason ROV enabled Dr Anna McCann to carry out a properly supervised archaeological survey and controlled recovery of artefacts. Much lighter systems are now available for work in shallow water down to 200m. During the last few years the use of AUV (autonomous underwater vehicle[39]) technology for the survey of the seafloor has become increasingly available and economic.

Due to the relatively limited bottom time (5-6 hours on average), slow speeds and human pilots, HOVs are best suited for direct-observation mapping and sampling rather than fine-resolution surveys. They can navigate freely in the underwater environment and are ideal for survey of rough seafloors. ROV surveys do not have the constraint on bottom time, but when working in the open sea and water more than a few tens of metres depth, it may require a dynamically positioned support

[39] AUVs operate independently from the ship whereas ROVs are connected by a cable to an operator on the ship.

ship which can cost from tens to hundreds of thousands of euros per day. Nowadays increasingly small ROVs are being used that can be operated quite cheaply from a small boat. The tethered configuration, however, limits the efficiency and effectiveness as robot and surface ship have to move in concert, and strong currents can exert drag on the umbilical cable.

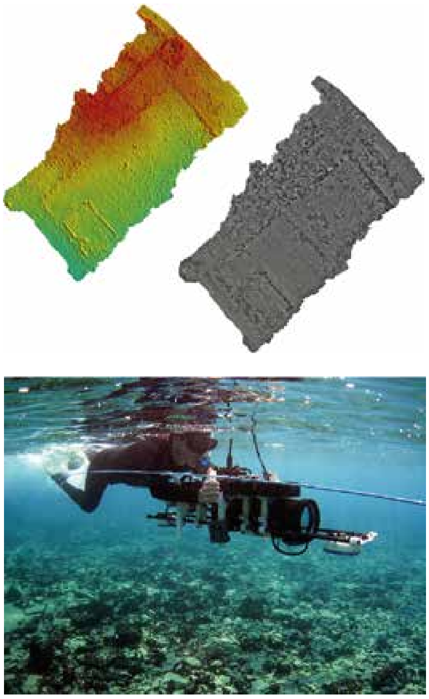
AUVs have proven their utility as a stable, controlled near-bottom survey platform. They are capable of flying precisely controlled fixed-altitude survey lines, making full use of short range optical or sonar resolution. They can operate from modest support ships (or from shore) and can survey large areas of the seafloor for 24-72 hours without returning to the surface.

Most commonly used sensors mounted on ROVs, HOVs and AUVs include navigation sensors for positioning, optical sensors (video, photographic, stereoscopic still cameras), sonar sensors for mapping the seafloor and its features (multibeam, side scan sonar, subbottom profiler) and chemical/environmental sensors for quantifying the oceanographic environment. Modern digital image recording, combined with accurate position fixing, facilitates the merging of hundreds or thousands of digital images into continuous optical maps.

Though a lot of progress has been made in underwater robotics and a variety of underwater vehicles has been used in shallow and deep water for different applications (from mapping to sampling and excavating deep water wrecks), carrying different payloads and sensors, so far their application for seabed prehistory and submerged shoreline studies has been astonishingly little. One of the few exceptions is the Pavlopetri project where an AUV was used for high resolution 3D mapping over a wide area and the optical identification of small surface artefacts. This approach could be developed for deeper work.

Credit: MMRG and Archivo ARQUA.

Fig. 6.9 Launching of an Autonomous Underwater Vehicle (AUV, left) and Remotely Operated Vehicle (ROV, right) for underwater archaeological surveys.



Credit: J. Henderson

Fig. 6.10 3D coloured relief (top left) and texture map (top right) showing wall remains (approx. 15 x 30 m) on the seafloor at the submerged archaeological site of Pavlopetri, Greece. The image was produced by geo-referenced stereo imagery from a diver-propelled platform (photo) combined with mapping techniques (Henderson *et al.,* 2013).

Photographic techniques

Underwater photography for scientific and archaeological purposes can be traced back to the 1930's, or even earlier. Since the 1950's both still and movie photography, combined with stereo methodology, have developed rapidly both for industrial applications, including survey, maintenance, damage assessment, etc., and in scientific and archaeological recording. With the introduction in recent decades of video and digital data recording, optical techniques have evolved to the point were hundreds or thousands of images can be obtained, stored, logged, and spatially referenced in a few hours.

The aim of photographic techniques is to produce a precise, three-dimensional map and image of the archaeological site. Rapid progress has been made, as increasingly high precision navigation and vehicle control permit a high precision positioning of the acquired photographic data. Photo- and videomosaicking techniques furthermore allow combination of photographic images with precision positioning.

Most common techniques for automated mosaicking make use of simultaneous localization and mapping (SLAM), augmented with techniques from computer vision and photogrammetry, to create a consistent set of image transformations (e.g. Bingham *et al.,* 2010). These techniques enable automated generation of strip mosaics, using data association between sequential images to produce a mosaic representing a single pass over the sight. Active research is going on with regard to multiple omnidirectional transects (Eustice *et al.,* 2008).

A recent advance in underwater photographic techniques is the creation of 3D reconstructions in parallel with generation of 2D photomosaic (Pizarro *et al.,* 2009) and the development of visually augmented navigation (VAN) (Eustice *et al.,* 2008). These techniques extract three-dimensional bathymetry estimates based on the collected photographic images. Integration of photographic and sampling technology is perfectly illustrated with the recently developed 'Sandcam' microscope camera, a so-called contact video microscope which provides high magnification CCTV images of seafloor sediments that are in contact with the viewing port of the camera.

Most of the discussed improvements in 2D and 3D optical imagery are related to the use of autonomous underwater vehicles, since AUVs have been proved more stable platforms than ROVs and HOVs, and are able to fly at constant altitude and speed above the seafloor. With the acoustical detection of small surface artefacts still being problematic, optical identification of the artefacts (in reasonably clear water), for instance using an AUV patrolling close to the seabed, would greatly help to identify sites.

6.3 Scientific diving technology

Diving is a high-quality and cost-effective research tool that supports a wide range of scientific disciplines (Sayer, 2007). It has particular use in difficult research environments such as subtidal structurally complex substrates or urbanized habitats that are inaccessible for study by conventional methods. Diving is used extensively in environments shallower than 50 metres water depth because of the physical and physiological limits of standard open-circuit air diving. However, there is an increasing acceptance of more advanced technical diving techniques that employ mixed gases, sometimes making use of rebreather units, to extend depths and durations of research dives.

Fig. 6.11 A diver records features of a submerged palaeoshoreline off the Farasan Islands.

Scientific diving has a good safety record. A recent review of over one million research dives indicated that the scientific and archaeological diving sector had the lowest recorded incidence rate compared with other sectors for decompression sicknesses and other diving-related injuries (Dardeau *et al.*, 2012). This safety probably arises through relatively high levels of training and supervision, the predominance of shallow, no-decompression diving and, possibly, low commercial pressure to complete dives under less than optimal circumstances. Increasingly there is a trend to standardize training and operational diving competencies. This promotes mobility and collaboration but has also been a main driver of raised basic standards in some countries. In Europe, the European Scientific Diver (ESD) and Advanced European Scientific Diver (AESD) qualifications are becoming the dominant recognized competencies for research diving. The qualifications are facilitated through the European Marine Board's European Scientific Diving Panel (ESDP); the ESDP represents all the National Committees in Europe that oversee scientific diving activity. There is a current initiative to place all scientific diving qualifications given around the world onto a single scale to increase the ease of facilitating collaborative diving projects.

Diving makes a significant contribution to a many science disciplines even though its impact in the literature is diluted through a lack of standardisation in how it is indexed (Sayer, 2007). Although much of science diving is based on traditional, though cost-effective, methods of placing the investigator underwater, there is a raft of emerging technologies that will underpin much of diving-based research in the coming decade. At the forefront is the need to develop low-cost accurate methods of geo-referencing the changing location of the diver. GPS signals do not penetrate underwater and so different techniques have to be adopted to enable the determination of accurate subtidal positioning. Long baseline (LBL), short baseline (SBL) and ultra-short baseline (USBL) techniques exist in the offshore industries for precisely placing divers and/or ROVs in three dimensions underwater. Although costly, these systems are of use to some underwater archaeology projects based on fixed sites. This is the general case on prehistoric sites. There have been preliminary attempts to produce diving computers that are linked, through a surface buoy, to a GPS signal (Kuch *et al.*, 2012) although offset in the linking wire can affect accuracy. In development are systems that are based on the positioning technologies produced for Autonomous Underwater Vehicles (AUVs) and Underwater Gliders. These systems take a GPS position immediately before diving and immediately on resurfacing. The dive profile is then calculated through interpolating between the two GPS fixes using inbuilt compasses, gyros and accelerometers. A prototype unit centred on smart-phone technology has been produced but currently lacks consistent accuracy. Much larger and more expensive navigation boards for divers, based on the AUV/glider systems, exist for military use.

Smart-phone and tablet technologies are perceived as being the platforms that will support most diving-based technological development in future. There are already proprietary underwater cases available for most models with some permitting underwater touchscreen usage (Leinikki *et al.*, 2013). Much of the potential for using "smart" technology underwater comes from the power of the computing available, the volume of data storage, and built-in cameras and video, GPS, accelerometers, and compasses. There are many potential applications with prototype underwater surveying tools (a combination of a smartphone and lasers), physico-chemical parameter loggers and even underwater routers that make use of the ability to transmit wirelessly underwater (although currently limited to about 1 metre distance).

Many terrestrial cutting edge methods for surveying are now being used underwater by divers. Three-dimensional mosaicking of camera or video stills permits the visualisation of large sites or objects that may not be obvious to the naked eye, particularly where underwater visibility is limited. The xyz point clouds generated during the visualisation processes also produce highly accurate methods of measurement (including volumetric quantification) in the laboratory. These methods are further optimising the time being spent underwater by the diver. Other developments are also contributing to increased efficiency. There are now a range of head-up displays available to the diver which means that a lot of the data that is necessary for the diving operation (such as depth, time, bearing, cylinder pressure) can be presented in a way that does not interrupt the main tasks being undertaken (Koss and Sieber, 2011).

6.2 Predictive modelling of submerged archaeological deposits

Underwater survey work, either based on remote sensing or on direct observations, remains an expensive, time consuming and complicated business. Acoustic systems are ideal to map past landscapes, but their effectiveness in actually pinpointing prehistoric sites or artefacts remains a challenge. Divers are restricted to the shallower parts of the continental shelf, and the use of underwater vehicles, no matter how promising, is still partly in its infancy. Furthermore these direct observations are of no use in the case of buried sites or material. The chance of locating archaeological artefacts based on intensive searching with acoustic systems in conjunction with diver (or ROV) survey still remains relatively small.

The wider scope of predictive modelling and its use for a range of different objectives have been discussed in Chapter 4. Here we address only the function of improving the probability of finding prehistoric anthropogenic sites on the sea floor, or proving their absence in the present situation. Predictive models can play a major role in submerged prehistoric research as they can greatly enhance the assessment of probability of site occurrence. If areas of high archaeological potential ('archaeological hot-spots') can be determined in advance, then surveys can focus intensively on these regions, hence reducing the time and expense. Furthermore, knowledge of areas of archaeological sensitivity can also provide a guide for shelf industrial concerns of where their work may affect the archaeological resource. The use of predictive models to facilitate the process of discovery has therefore been proposed and attempted for a number of decades now (e.g. Gagliano *et al.*, 1982). However the range of applications is large, with many different environments and cultures, and success rates so far rather low, or at least very variable, in this particular role, with the notable exception of the southern Baltic, where the time required for divers to locate a site can be significantly reduced.

Predictive modelling is evolving rapidly, and has great potential, but substantial effort is still needed to ensure that applications in the field are effective, rather than experimental.

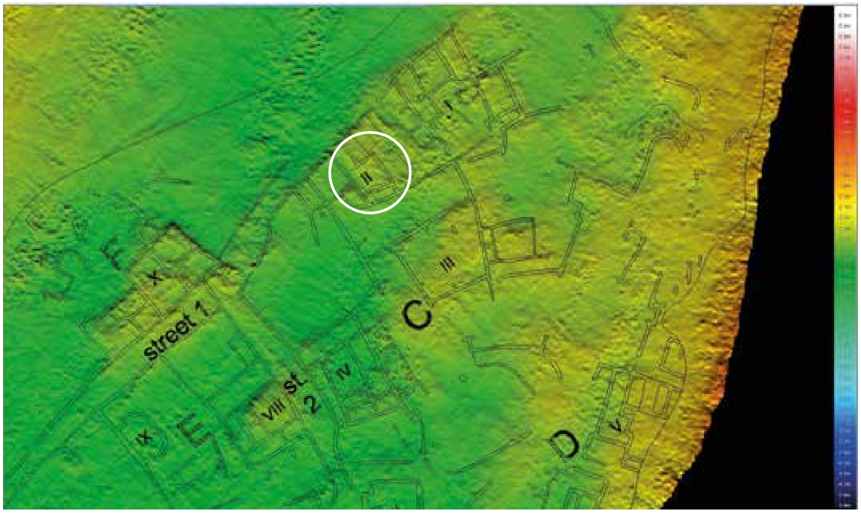
Case study 1: Pavlopetri – innovative sonar and photogrammetry imaging

Pavlopetri, located at southeastern edge of Peloponnese in Greece, is the oldest submerged city dated from at least 3,500 yr BC through to the end of the Mycenaean period ca. 1,180 BC. Remains can be traced over 8 hectares ($8x10^4$ m²), submerged by 3-4 m of water depth, and consist of intact domestic buildings, larger public structures, courtyards, streets, graves and rock-cut tombs.

The aim of the multi-national, multi-disciplinary Pavlopetri Underwater Archaeological Project 2009-2013[40] was to (i) to reconstruct the submerged prehistoric landscape, (ii) to understand the geological processes which led to the drowning of the city and (iii) to use and test innovative and conventional mapping techniques and methodologies for the survey and documentation of the submerged city.

The site was surveyed with side scan sonar, multibeam echo sounder, sector scan sonar, diver-operated photogrammetry-rig and with AUV stereo-photography (Mahon *et al.*, 2011). Offshore geological survey with multi-beam, subbottom profiler and side scan sonar as well as geological mapping of the broad region aimed at understanding the role of vertical tectonics and Holocene sea level rise in the submergence of the city.

[40]Partners: University of Nottingham, British Archaeological School at Athens, Ephorate of Underwater Antiquities, Hellenic Centre for Marine Research in collaboration with the National Oceanography Center, UK and the Australian Center for Field Robotics http://www.nottingham.ac.uk/pavlopetri/projectoverview2009-2013.aspx



Credit: Pavlopetri Project

Fig. 6.12 Total plan of the submerged ruins of Pavlopetri superimposed upon an ultra-high resolution (10x10cm) bathymetric map of the site. Bottom image is the underwater view of Building II.

Very high resolution side scan sonar prospecting (400 kHz) revealed the overview texture of the archaeological remains. A parametric multibeam echosounder was used to acquire ultra-high resolution bathymetry of the archaeological site. Both techniques were proved very reliable and provided accurate and high quality acoustic and bathymetric maps, compatible with the plan produced by the Total Station measurements by divers. Stereo-photogrammetry of the submerged archaeological site was conducted with the use of an innovative, diver-operated rig designed by the Australian Centre for Field Robotics. The high resolution mosaics were processed and produced accurate three dimensional models of the seafloor with the archaeological remains.

Case study 2: Rotterdam (Yangtze) harbour – finding the needle in a haystack

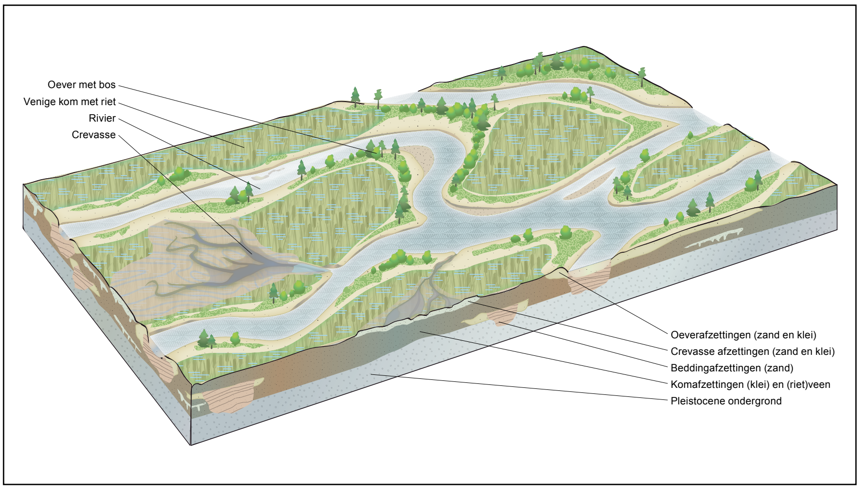
The Port of Rotterdam is at present expanding its harbour into the North Sea (See also p. 61-62). A new 20m deep, 3km long, and 500m wide harbour canal (part of the Maasvlakte 2) is being dredged to connect to the existing harbour, thereby destroying buried Early Holocene drowned fluvio-deltaic landscapes. Archaeological research in deposits of the Early Holocene age further upstream in the Rhine delta had already revealed that Mesolithic hunter-gatherers adapted to the drowning landscape by using the highest parts of Late-Weichselian aeolian dunes for their hunting camps.

This combined knowledge led to the challenge of finding such dunes in the harbour, and possible related archaeological artefacts. At depths of 17–22m below the seafloor, and in 17m water depth, this was like looking for a needle in a haystack. In 2008 a special agreement between the Port of Rotterdam, The Netherlands Cultural Heritage Agency (RCE) and Rotterdam Archaeological Department (BOOR) was set up for archaeological research.

A combination of very detailed high-resolution sub-bottom profiling, cone penetration tests and piston cores was used to pinpoint the areas with a high archaeological potential. Remnants of a river dune and filled-in fluvial channels were found, in addition to numerous archaeological remains (mainly on top of the river dune), predominantly charcoal but also (burnt) flint fragments. This led to further underwater investigations in 2011. A special crane was used to remove the sediments just above the level with archaeological remains on three locations on the dune. This level was carefully excavated using a special scraping grab with exact horizontal and vertical positioning. Careful sieving of the retrieved sediment resulted in many spectacular finds of well preserved (early) Mesolithic remains including organics.

Credit: D.E.A. Schiltmans/ Port of Rotterdam and City of Rotterdam Archaeological Service

Fig. 6.13 (Top left) Excavation pontoon used for the archaeological investigations in Yangtze harbour.
(Top middle) Fragments of flint stones and (Top right) bones found at Yangtze harbour.
(Right) Landscape offshore Rotterdam during the early Holocene: a freshwater deltaic setting with meandering rivers.



Credit: Weerts et al., 2012.

Case study 3: Submerged caves

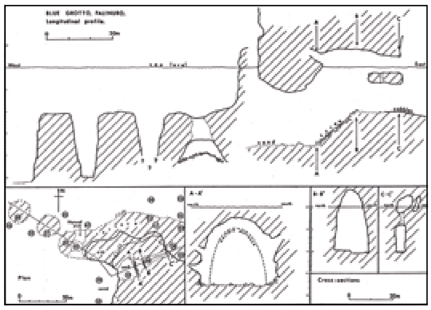
Submerged caves have been explored by divers for prehistoric associations since the 1960's. The most famous discovery was the Grotte Cosquer, near Marseille, France, in the early 90's, when cave paintings dating to 19,000-27,000 BP were found on the walls of a cavern which could only be entered through a flooded tunnel at 40m depth in the sea. Other submerged caves in Italy have revealed deposits of terrestrial fauna, and suggestions of human access, but with few finds in stratigraphic context. Caves off the south west headland of Gibraltar at a depth of 20m have also produced tentative evidence of terrestrial deposits and encrustation dating before the LGM. Submerged caves containing terrestrial speleothems have frequently been studied, but have not so far yielded human indicators.

Credit: D. Sakellariou

Fig. 6.14 Spectacular series of continuous ripple notches, cut into cliffs of Mesozoic limestone on Eastern Rhodes Island (Greece), indicate at least six tectonically uplifted and superimposed shorelines from Late Holocene. The uppermost and older shoreline at +3.75 m is a well preserved tidal notch and the corresponding sea level has been dated 4,895 ±100 yr B.P. (Pirazzoli *et al.,* 1989). The partly submerged cave, with cave floor at 5-10 m below the sea-level, is being exploited as a touristic site.

The typical cave found below sea level is partly the mouth of a karstic drainage system from further back in the cliff, and partly a wave-eroded sea cave, with a wide mouth and associated rock falls from cliff retreat. Thousands of subsea caves have been explored by diving speleologists, and many have been studied by marine biologists for their curious marine growths. An area that has been intensively mapped is the narrow rocky continental shelf within a few tens of km either side of Marseille, France, which includes the Grotte Cosquer (Flemming, 1968 & 1972; Bonifay and Courtin, 1998; Collina-Gerard, 1992 & 2004). On the limestone rocks outcropping along the Italian coastline there are well developed karstic systems which were active during the sea-level lowstand in glacial periods. Many submerged caves are known but only partially studied. Two important books have been published describing with details hundreds of sea-flooded caves with sketches, sections and scientific (geological, biological and ecological information: Alvisi *et al.,* 1994, Cicogna *et al.,* 2003). The difficulty from the perspective of prehistoric archaeology is deciding which caves are worth excavating as potentially productive of artefacts. The removal of rock debris requires powerful tools, and sometimes the ability to lift heavy rocks. Anthropogenic relics are most likely to be found encrusted or cemented to heavy rocks, or the cave wall, which would protect them from erosion.

At present no standard technologies are available for detailed acoustic mapping of cavities and caves even if special sonar devices could be mounted on ROV vehicles for this purpose. Representation of vertical (not to say concave) surfaces is problematic with standard softwares used to analyse digital terrain elevation models. Survey of submarine caves therefore relies on standard "low-tech" methods such as: First a general overview of the cave with a videocamera equipped with a headlight ("GoPro"-like) has to be conducted to get an idea of forms and cave deposits. After analysing the videos, a cave dive will be planned with the aim to study and sample the evidences found in the video survey.



(Flemming, 1968)

Fig. 6.15 Survey sketch made by divers of a cave at Palinuro, Italy. The cave extends to an erosional terrace now 50m below sea level, and shows the typical characteristics of a sea cave cut in limestone. At the point of the headland there are two free-standing "stacks" or "secs", and a rock arch from which part of the roof has fallen in. These rise from a terrace at -50m, and are all planed off at a depth of 20m. The main cave penetrates through the headland, with an eastern entrance at 20m depth, and an internal scree slope down towards the western entrance at 50m depth.

In the circumstances of the particular very conservative and low energy restricted environment it is necessary to observe strict safety rules of cave diving encompassing technical equipment, lighting, use of a lifeline (Ariadne's rope). A safe return out of the cave is in fact frequently hindered by low to zero visibility due to the suspension of very fine deposits stirred up by the passage of divers. This kind of research should therefore be programmed in detail and carried out by experienced personnel. The presence of a metre or more blanket of clay and silt on the bottom of the caves limits the immediate findings to the wall and roof of the caves and it is very unusual to dig the deposit at the bottom of the caves that usually contains the majority of prehistoric findings. As a result, the more frequent finding in underwater caves consists of stalactites and stalagmites (Antonioli *et al.,* 2004 and Dutton *et al.,* 2009a&b) or flowstones (Richards *et al.,* 1994), often stratified with hiatus or marine overgrowth. The case of the cave Cosquer is exceptional as an underwater corridor leading to a room above present sea level containing painting and graffiti (Clottes and Courtin, 1994).

6.3 Future challenges

In spite of current advancement of high-performance technology, there remain a large number of challenges for the future, notably to increase the methodologically-predicted finds more than chance finds. This will not only require a better reliability of the remote sensing data (i.e. the confirmation of a prehistoric site without actual seabed examination or large-scale physical sampling), but also a better cost-efficiency (i.e. improved search for and integration of existing data). A second important challenge is direct observations after the site has been found for an efficient sampling, documentation, excavation, especially in deeper water.

In addition to these general challenges, a number of specific technological challenges exist:

Detection of small buried artefacts (flints and bone)

Identifying small objects buried beneath the seabed is still a tremendous task. This is not only due to the resolution of the current acoustic imaging systems (limited to a few dm at best), but also the (acoustic) contrast between the object and the surrounding sediments that may not be sufficient. Buried Stone Age sites are difficult to locate, as their cultural layers are often embedded in and protected by soft sediments such as mud or peat. Yet these sites often contain many hundred, if not a few thousand, of man-made flint blades and flakes, and their acoustic detection remains a huge challenge. Ongoing Danish-Belgian research focuses on the acoustic features of worked flint, in specific the resonance pattern (assuming that objects of similar geometry and material, such as flint blades and flakes, will have a similar pattern) (Ren *et al.,* 2012). Although the first results from lab studies are promising extensive further research is needed.

Effective image recognition of the seabed

Systems to recognize prehistoric relics on the seabed in an efficient way are required. Accurate object identification on sonar data is a difficult task, and often it is not possible to differentiate between seafloor areas that contain features of archaeological significance and areas that are barren. Video is good at seeing features but is not capable of providing quantitative assessments. Even close-up photography from an ROV or towed system is almost impossible to interpret unless you know what to look at, as was the case at Pavlopetri. So far the only way to confirm a prehistoric site is to dive on it or take large physical samples. Future research is needed into combining the information of full backscatter maps, high resolution bathymetry and photographic data in a smart and efficient way. An important step was taken in recent years with the development of an efficient and easy to deploy Underwater Laser Scanning (ULS) system (Gillham, 2011).

Excavating in deep water

Underwater expeditions with HOVs, ROVs and AUVs have yielded spectacular findings on the seafloor and produced high quality results particularly in deep and shallow water shipwreck archaeology. The main use of HOV, ROV and AUV so far is in documenting, remote sensing and sampling (and at its best digging trial trenches). An important challenge for the future is to advance their use from visual surveys and incidental salvage to real excavations. This will require highly delicate (and remotely controlled) robotic manoeuvring which poses an engineering challenge.

Detection of and excavation in cave sites

Conventional seafloor mapping is based on a plan view projection, which is not suitable for exploration of nearly vertical limestone walls where cave entrances may be found. Very-large-swath multibeam systems, currently used for shallow water inspection of harbour structures (pier, artificial reef, seawall, and etc.) can be adapted to ROV for deeper water use. DEM-rendering software used for multibeam and side scan sonar data interpretation could be modified to manage 3D data. Once the cave entrance has been detected, examination of the inside of the cave requires identifying concretion on the cave walls, fallen debris, wind-blown or wave driven sediments, roof falls, and accumulated earth which may contain archaeological materials. Techniques to carry out these tasks efficiently have not been tested, and the risk of failure has deterred trials. This area needs intensive study to find a way forward.

Salvage of undisturbed large samples

Currently available technology for the salvaging of samples and cores in marine waters by drilling allows us to cut off samples of up to 30cm in width for geochemical, sedimentological or palynological analyses for information to reconstruct palaeoenvironmentals. However such samples are inappropriate for the salvaging of archaeological features. There is still a need for developing techniques for the salvage of undisturbed big scale sediment blocks. This technique has to be used if there are indications of well-preserved prehistoric features (e.g. huts, fireplaces, log-boats, graves) that cannot be thoroughly investigated and documented on the sea bed and that will be destroyed by construction works etc. The recovery of sediment blocks in similar situations has become a routine in land-based archaeology for a long time; on the one hand it allows the detailed investigation of the particular feature under laboratory conditions, on the other hand it enables the immediate continuation of construction works on site after the blocks are retrieved.

Geochemical / DNA analysis

Currently, samples or core material are only investigated with regard to dating and palaeoenvironmental (pollen) analysis. Geochemical analysis of cores/samples to identify anthropogenic disturbance or contamination still remains an unexplored subject. Although this technique may not serve to locate a site to within a few metres, or to detect a flint, it may help to detect an area within which humans were active so as to reduce the scale of the survey area (from km to m scale). The possible identification of chemical-biogenic signatures that are typical of human occupation would represent an important step forward in Continental Shelf Prehistoric Research.

SUMMARY

Due to the wide variety in encountered scale, environment and stage of application, submerged prehistory research involves a large spectrum of technologies. This goes from acoustic, magnetic and Lidar remote sensing over coring and sampling, diving surveys, and the use of underwater vehicles to predictive modeling techniques. These technologies are evolving rapidly and have resulted in an increasing number of reported sites, but need to be exploited to their limits.

A lot of techniques were developed for other purposes (e.g. geological or terrestrial studies, military research) and they are often aimed at shallow water environments. In order to adapt the existing techniques to the specific needs of submerged prehistory research and to advance deeper water investigations (down to 150m), improvements in survey techniques and underwater work are needed.

It is therefore crucial to set up a 'best practice' approach, from general reconnaissance surveys to the localisation and sites investigation at small scale. This approach supports decision making throughout research progress and to the Environmental Impact Assessment before the research is carried out.

Continental Shelf Prehistoric Research involves large data volumes from a wide range of sources. New developments in software are crucial for the integration of these data, but also for landscape reconstruction and predictive modeling. The latter is playing an increasingly important role in the detection of submerged cultural heritage in hitherto unsurveyed areas.

The improvement and new development of specific prospection tools and software requires sufficient resources which can only be achieved through increased scientific budgets, both on a national and on an international scale. A close collaboration with the marine industry (offshore hydrocarbons, dredging, civil engineering, wind farm installation, and etc.) will not only enhance the (technological) research but it will also allow doing so at a reduced cost.

A final, but important, aspect is the availability of new technology. As described in this chapter, there is a large potential in technology but its access is often restricted. Collaboration between national institutions to share expertise and techniques is therefore crucial. High-technology data acquisition and processing requires experienced people and trained operators. This collaboration is largely interdisciplinary in view of the wide range of techniques and data that need to be integrated.

High-quality marine research requires availability and optimally-coordinated access to ship time. The Eurofleets2 project (FP7) is a valuable example in this aspect, which facilitates the access to European research vessels and ship-time (www.eurofleets.eu) and provides a number of courses for multidisciplinary ship-based training in equipment operation, sample, data acquisition andprocessing. The Eurofleets project opens new perspectives for large-scale palaeolandscape mapping programmes, and small research projects can benefit strongly from it.

7

A European Research Strategy for Continental Shelf Prehistoric Research

Credit: V. Gaffney

The continental shelf of Europe, which was exposed subaereally for much of the last million years, added 40% to the present land area and was occupied by prehistoric peoples. This substantially changes the basis for understanding and interpreting the early human occupation of the European continent and the origins of its present populations. In addition, it presents an opportunity to uncover important new insights on early marine exploitation, climate changes, human response to sea level change, and migration routes into Europe. Past work by scattered research groups around Europe, and particularly the co-ordinating COST Action SPLASHCOS, has developed a momentum which establishes Europe as a world leader in this research topic. This provides the basis for exporting expertise and research skills. The volume of prehistoric material found and catalogued from the sea floor is now very substantial (Fig. 7.1), and amounts to far more than a few chance finds. We now know that the variety of drowned prehistoric settlements and artefacts of many ages, and the associated fauna and flora from past climates, make it a culturally important part of Europe's heritage.

Credit: D. Mol

Fig. 7.1 Fishermen unload the skull of a woolly Mammoth complete with molars and one tusk, trawled from the floor of the North Sea.

The conclusions and recommendations from this review of Continental Shelf Prehistoric Research are numerous; some are general and high-level, while others are specific and narrowly focused. We will start by reviewing the strengths and weaknesses of the case (SWOT analysis) for developing and supporting Continental Shelf Prehistoric Research; then summarize briefly the lessons learnt by the collaborative work in preparing this position paper; and finally list the broad conclusions and recommendations. More detailed recommendations are provided under the same headings in Annex 4.

European continental shelf with maximum extent in red of exposed land 20,000 years ago.

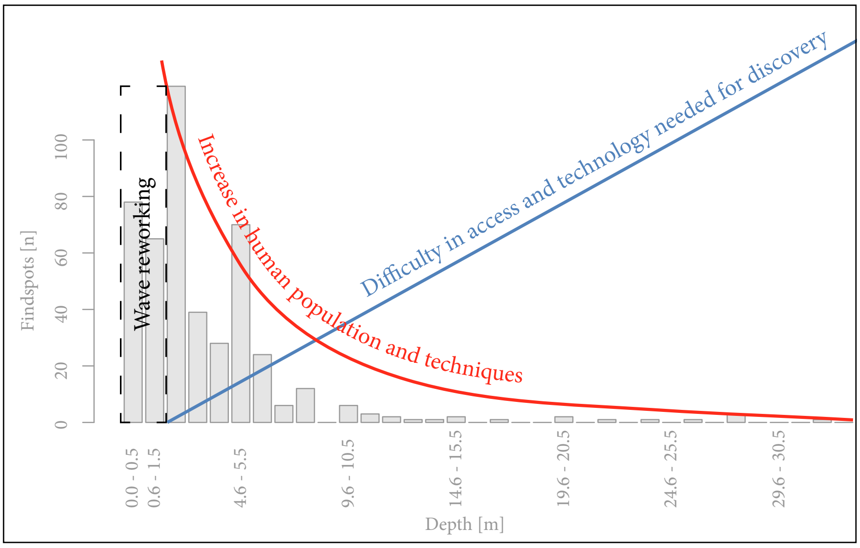
7.1 SWOT analysis of Continental Shelf Prehistoric Research

Strengths	Weaknesses (= Challenges)
• Much of human prehistory is underwater- Europe was 40% larger during the last Ice Age, and practical evidence shows that a significant proportion of prehistoric Underwater Cultural Heritage has survived the Pleistocene sea-level fluctuations; • World-class concentration of European skills and disciplines in varied technological and archaeological institutes; • Wide, dedicated, multi-national and multi-disciplinary community (>200 engineers, archaeologists and representatives from national science laboratories and cultural heritage agencies of >25 European countries) brought together by the COST Action, SPLASHCOS (2009-2013); • A core of 50+ dedicated organizers from SPLASHCOS and Deukalion Planning Group; • Obligations under relevant treaties and directives: UNCLOS, Valetta, UNESCO Underwater Cultural Heritage, and European policies on pre-licensing surveys, Marine Strategy Framework Directives, Maritime Spatial Planning, Marine Knowledge 2020 and Blue Growth. • High-resolution mapping of palaeoshorelines improves sea-level computation for past dates; • Modern survey techniques enable high-resolution reconstruction of the submerged landscapes and vegetation; • Engagement of the diving community, archaeological research divers, professional scientific divers, and amateur diving clubs.	• There is a shortage of trained personnel in this field; existing small research groups can collapse or break up, resulting in a loss of valuable experience and skills, and losing continuity; • Continental Shelf Prehistoric Research and conservation are seldom mentioned in standard courses on marine archaeology; • Marine/underwater geo-archaeological surveys are high-cost activities, in the order of tens to hundreds of K€ or even M€ for comparative studies; • While amateurs and commercial operators continue to discover sites and chance finds, the follow-up has been insufficient; • Sources of funding are fragmented and mostly at national level; • Research on submerged cultural heritage is not among the funding priorities of the European Commission (e.g. Horizon 2020); • Limited access of archaeological institutions to state-of-the-art survey techniques; • No regular collaboration established with industrial sectors. Communication is crucial to exchange information between stakeholders (industry, scientists and policy-makers) about human factor and cultural heritage in seabed mapping; • Need for multi-disciplinary approach integrating science, archaeology, heritage, technology and industry in sustainable management of the continental shelf; • Relatively small parts of the continental shelf seabed have been studied/ mapped at very high resolution; • Limited or no access to large quantities of acoustic data which are still held as classified, though often of no commercial value.

Opportunities	Threats
• Archives already hold petabytes of digital geo-science data on the European continental shelf and its palaeo-environments; these can be integrated to recreate landscapes; • Inter-disciplinary, cross-cutting, humanities-sciences interface can be enhanced; • Improved collaboration between offshore industry and research community can reduce costs to industry and provide the research community with valuable data and opportunities; • Contribute to the European marine policies by providing important clues for the sustainable exploitation and use of the shallow seafloor, particularly regarding exploration/exploitation of non-living resources, e.g. oil & gas, wind energy, aggregates, rare-earth elements deposits; • Early integration of ecosystem data with cultural heritage surveys would avoid extra expenses; • Engage diving community in reporting potential discoveries; • Pan-European network of interdisciplinary skills, collaboration with industry, public outreach and communication (ocean literacy); • Ground-truthing for technology of small-object detection, and high-resolution calibration of palaeoenvironmental models (sea-level, climate, vegetation); • Assistance to sustainable management: need for integration of multi-user seabed spatial planning; • Facilities provided by modern IT systems with massive data storage capacity, rapid transfer of large volumes of data, numerical models, and new dedicated spatial data management systems will advance Continental Shelf Prehistoric Research; • Improved models of sea-level change, verified and checked by field data, delineate more accurately the past shorelines and enable verification of the plausibility of future shoreline scenarios; • Increase the possibility of finding new sites and landscapes by replacing chance discoveries with targeted survey.	• Climate change and environmental and biological changes offshore are changing seabed stability, and increasing erosion and bio-erosion; • The cost of protection and preservation of sites is high, and many cannot be protected from natural erosion; • Increasing industrial activity, bottom trawling, aggregate dredging, harbour and channel construction, cable and pipe-laying, and wind-farm construction, all disturb the sediments of the sea floor on a large scale, and have the potential to destroy prehistoric deposits; • National and European regulations and directives pay too little attention to the implementation of protection for submerged prehistoric landscapes, and to the research needed to plan protection, although over-arching treaties and obligations state that protection is necessary.

7.2 Conclusions and recommendations

The SPLASHCOS database on submerged prehistoric sites provides the data from which to analyse how and where sites survive, and how difficult or easy it is to find them and study them. Analysis of the environments in which most submerged prehistoric sites have been found will help to improve predictive models, although much work is still needed to additionally relate site survival to land gradient, rate of marine transgression, local coastal topography, and terrestrial substrate. Depth is a key factor, whereby the potential for finding sites decreases with depth and this is further compounded by the greater difficulty of working at depth (Fig. 7.2).



Credit: F.L. Chiocci & M. Mennenga

Fig. 7.2 The background grey data shows the depth of all submerged prehistoric sites registered by March 2014 in the SPLASHCOS data base. The number of known sites decreases rapidly with depth. The red curve uses arbitrary units to indicate that the population density and tool technology decreases as we go back in time and depth; while the blue line indicates the increasing cost and technical difficulty of working at depth.

Fig. 7.2 rationalizes the presumption that prehistoric sites were distributed more or less equally on the different exposed land masses around Europe, excluding those areas under ice, and that the population density increased as social and technological factors evolved, and people abandoned flooded areas, moving up-gradient and northwards. Very close to sea level the number of sites reported is less than in shallow water, probably due to constant wave action and tidal scour, although some sites do survive in intertidal waters.

It is apparent from the collation of SPLASHCOS data that more sites have been discovered so far in the wide shelf seas with extensive sediment transport, low gradients, both accumulation and erosion, and fewer in the Mediterranean with its steep rocky shores and lower sedimentation. While the Mediterranean coastline is less easy to investigate, and chance finds are much fewer, there have been regional successes, for example in areas such as the coast of Croatia, and the northern Mediterranean coast of Israel. The successes in these regions have been largely driven by the establishment of groups that have dedicated special effort to identifying their local coastal prehistoric conditions. Scattered sites in Italy, especially off the island of Pantelleria, and the French Grotte Cosquer near Marseille, suggest that there is a great deal more to be discovered if we can develop the right techniques and search in the right environmental niches. A greatly increased effort is needed to identify what kinds of sites did exist in the sparse areas, and in what micro-niche environments they may have survived.

Technology is evolving rapidly to provide increased confidence and efficiency in finding sites, mapping them, and making the critical decisions about more detailed survey, assessment, test excavation, preservation *in situ*, abandonment, or full excavation.

Predictive modelling will play an increasing role in both research and management of the offshore cultural heritage. Models can be used to indicate the probable site density in unsurveyed areas; the probability of site occurrence in relation to known prehistoric submerged landscape and previous site characteristics; and to model the processes of both site location and modification by inundation.

Access to very high data volumes is essential both for research and cultural heritage management. This means combining data from many sources, both in the geosciences and archaeology, and developing new and improved software for interfacing these types of data in the continental shelf environment.

The understanding of the distribution and characteristics of continental shelf prehistoric sites will contribute to a change in the way archaeologists perceive the early development of social complexity in Europe and the Middle East. A combination of maritime and coastal technologies with exploitation of food and fresh water on coastal plains suggests that settlements on the coast, now submerged, were developing levels of organization and social hierarchy before the development of agriculture in the so-called “Neolithic Revolution”. A set of research themes has been proposed (Chapter 3, and summarized in the full conclusions in Annex 4) focusing on the complexity of early coastal settlements, migration pathways between Africa, the Middle East and Europe at different stages of the multi-glacial cycles, early stages of navigation and exploitation of islands in archipelagos, the earliest stages of seafaring, response to sea level change both rising and falling, the spread of farming along the North Mediterranean coastal lands (now submerged), and the systematic integration of the continental shelf prehistoric data with the archaeology of the same periods on land, facilitating a complete European view of prehistory.

Continental Shelf Prehistoric Research must take its place as a recognized new discipline supporting both prehistoric archaeological research with related academic training, and supporting cultural heritage management and compliance with international treaties, European regulations and directives, and national policies on cultural heritage. However, treaties, directives, and regulations that require protection of the submerged prehistoric heritage are not matched by the scale of funds and research support necessary to implement them. Many actions required by European directives involve high resolution surveys of the sea floor and below the sea floor, and many of the variables recorded are similar to those required for archaeological research and cultural heritage management. It is, therefore, desirable that protocols or guidelines are developed which can include the measurement and assessment of seabed archaeological resources, both shipwrecks and submerged prehistoric archaeology, when such surveys are carried out. This would provide significant economic benefit and certainty for offshore operators, both commercial and governmental, since issues of cultural heritage protection would not emerge as unpredictable surprises after projects have been approved and licenses granted.

Continental Shelf Prehistoric Research is a composite and integrative discipline, depending closely upon research in many other sectors. The need for integration is both from the research side (where prehistoric archaeology meets marine sciences) and on the technological side (where remote sensing - mainly geophysics meets scuba diving and excavation).

The necessary links to these disciplines have been identified, so that the research groups studying the basic Quaternary processes include the hominin scale in their project designs. It is clearly much more efficient to build collaboration in at the project planning stage rather than trying to establish it after that project has started.

Broad conclusions follow under the following categories: Procedural, Strategy, Archaeological Objectives, Training and Education, Geoscience Objectives, Funding Sources, Industrial Collaboration, Technology, and Data Access. The detailed recommendations and conclusions under each of these headings are listed in Annex 4.

Procedural, regulatory and institutional

National and European agencies and institutions need to include Continental Shelf Prehistoric Research in Marine Spatial Planning, in their compliance with European Directives, in research funding programmes and encourage stronger collaboration between marine geoscience institutes and cultural heritage agencies.

Strategy

Continental Shelf Prehistoric Research should be planned and implemented at the sea basin scale, and continuous collaboration is needed between offshore industries, cultural heritage agencies, university researchers, and marine planners. Research should be conducted in the knowledge that sites are being continuously lost through climate change, erosion, and damage by offshore operations.

Archaeological objectives

A list of priority archaeological goals that will help to fill in the gaps missing in European prehistory is provided in Annex 4. Long-term and consistent planning and collaboration between the humanities and marine geoscience research communities is needed, including integration of archaeological data with human genetic data on migrations and population groups.

Training, education, publication, web services

Training and education need improvement at every level, requiring the appointment of dedicated professorships, improvements and expansion of courses, technology transfer, public awareness, contact with amateurs, divers, and stakeholders, and improved knowledge interaction between research, cultural heritage management, and industry.

Funding sources

The multi-disciplinary and trans-border nature of Continental Shelf Prehistoric Research means that many of its priority objectives fall outside, or exceed, national agency terms of reference, and tend to divide across several EC research themes. The societal challenge structure of the Horizon 2020 programme is well placed to address the cross-disciplinary support necessary to advance this research field. Funding from the Horizon 2020 programme could provide a coordinating boost to leverage increased investment by member states, either through their own research funding mechanisms, or collaboratively through the relevant Joint Programming Initiatives.

Geoscience objectives

Continental Shelf Prehistoric Research requires very high resolution reconstructions of the ice caps, ice edge, and peri-glacial climate, together with accurate sea level curves, GIA models, and palaeo-vegetation. The demands of accuracy and integration of variables will reveal details of the palaeo-environment, river patterns, shorelines, etc., which would have been difficult to synthesize in any other way.

Industrial collaboration, stakeholders, partners

A wide range of industries, including fishing, dredging, offshore hydrocarbons, civil engineering, beach replenishment, windfarm installation, and cable and pipe-laying, require disturbance of the sea floor and can uncover or destroy prehistoric remains. These industries can collaborate with cultural heritage agencies and research institutes both to enhance research, and to reduce the cost and complexity of enforcing conditions of licensing.

Technology

This research needs to fully exploit current and emerging technologies and to promote improvements in acoustic survey techniques, enhanced ability to conduct prolonged heavy and accurate work on the seabed, commercial and scientific diving, the application of ROVs and AUVs, and developments in related site detection, use of geochemical techniques, and development and testing of software for data integration and landscape reconstruction.

Data access, archiving and processing

Large quantities of relevant data are currently held in hundreds of national agencies and archives, part of which has been integrated, at least at the metadata level, by EMODnet. Long term re-structuring and improved access to data is required to develop European-wide data sets, access to existing data, and release of large quantities of classified data which has no commercial value. Improved software is needed to reconstruct palaeo-landscapes from raw data.

References

Aksu, A.E., Hiscott, R.N., Kaminski, M.A., Mudie, P.J., Gillespie, H., Abrojano, T., Yaşar, D. (2002) Last glacial-Holocene paleoceanography of the Black Sea and Marmara Sea: stable isotopic, foraminiferal and coccolith evidence. Marine Geology 190, 119-149.

Aksu, A.E., Hiscott, R.N., Yaşar, D. (1999) Oscillating Quaternary water levels of the Marmara Sea and vigorous outflow into the Aegean Sea from the Marmara Sea–Black Sea drainage corridor. Marine Geology 153, 275-302.

Alvisi, M., Colantoni, P., Forti, P. (1994) Memorie dell'Istituto Italiano di Speleologia 186 pp.

Andersen, S.H. (2013) Tybrind Vig: Submerged Mesolithic Settlements in Denmark (Jutland Archaeological Society Publications) Denmark. 327pp.

Andrén, T., Andrén, E., Berglund, B.E., Yu, S.-Y. (2007) New insights on the Yoldia Sea low stand in the Blekinge archipelago, southern Baltic Sea. GFF, 129(4), 277-285.

Andrén, T., Björck, S., Andrén, E., Conley, D. J., Lambeck, K., Zillén, L. (2011) The development of the Baltic Sea basin during the last 130 000 years. In: Jan Harff, Svante Björck, Peer Hoth (Ed.), The Baltic Sea Basin. Paper presented at 33rd International Geological Congress, Oslo, August 11, 2008. (pp. 75-97).

Antonioli, F., Ferranti L., Lambeck, K., Kershaw, S., Verrubbi, V., Dai Pra, G. (2006) Late Pleistocene to Holocene record of changing uplift rates in southern Calabria and eastern Sicily (southern Italy, Central Mediterranean Sea). Tectonophysics, 422, 23-40.

Antonioli, F., Vai, G.B., Cantelli, L. (2004) Litho-Palaeoenvironmental maps of Italy during the last two climatic extremes two maps 1:1.000.000. Climex Maps, explanatory notes edited by Antonioli, F. and Vai, G.B., SELCA Firenze 32° IGC publications.

Andrew, J, Cooper, G., Pilkey, O.H. (2004) Sea-level rise and shoreline retreat: time to abandon the Bruun Rule. Global Planetary Change. 45, 157-171.

Antonioli, F., Bard, E., Silenzi, S., Potter, E.K., Improta S. (2004) 215-ka History of sea-level oscillation from marine and continental layers in Argentarola Cave speleothems (Italy). Global and Planetary Change, 43(1-2), 57-78.

Armijo, R., Meyer, B., King, G.C.P., Rigo, A., Papanastassiou, D. (1996) Quaternary evolution of the Corinth Rift and its implication for the late Cenozoic evolution of the Aegean. Geophys. J. Int., 126, 11-53.

Ashton, N., Lewis, S.G., De Groote, I., Duffy, S., Bates, M., Bates, R., Hoare, P., Parfitt, S.A., Peglar, S., Williams, C., Stringer, C. (2014) Hominin Footprints from Early Pleistocene Deposits at Happisburgh, UK. PLoS ONE 9(2):e88329. doi: 10.1371/journal.pone.0088329.

Bahr, A., Lamy, F., Arz, H.W., Major, C.O., Kwiecien, O., Wefer, G. (2008) Abrupt changes of temperature and water chemistry in the late Pleistocene and early Holocene Black Sea. Geochemistry, Geophysics, Geosystems, Vol. 9, Q01004, doi:10.1029/2007GC001683.

Baika, K. (2008) Archaeological indicators of relative sea-level changes in the Attico-Cycladic massif: preliminary results, Bulletin of the Geological Society of Greece XLII (II):33-48.

Bailey, G.N. and Flemming, N.C. (2008) Archaeology of the continental shelf: marine resources, submerged landscapes and underwater archaeology, Quaternary Science Reviews, 3-24, 2153-65.

Ballard, R.D. (1993) The JASON remotely operated vehicle system. Technical report, WHOI-93-34, Woods Hole Oceanographic Institution.

Bass, G.F. (1968) New Tools for Undersea Archaeology. National Geographic, 134(3), 402-423.

Bates, R., Lawrence, M., Dean, M. & Robertson, P. (2011) Geophysical methods for wreck-site monitoring: the Rapid Archaeological Site Surveying and Evaluation Programme. Nautical Archaeology, 40(2), 404-416.

Belknap, D.F. and J.C. Kraft (1981) Preservation potential of transgressive coastal lithosomes on the U.S. Atlantic Shelf marine. Geology 42:429-442.

Benjamin, J., Bonsall, C., Pickard, C., and Fischer, A. (2011) (eds). Submerged Prehistory, papers presented at the 2009 Conference of the European Archaeologists' Association. Oxbow Books, 352p. ISBN-13:978-1-84217-418-0.

Bennike, O. and Jensen, J.B. (2011) Postglacial relative shore level changes in Lillebælt, Denmark. Geological Survey of Denmark and Greenland Bulletin 23, 37-40.

Berglund, M. (2004) Holocene shore displacement and chronology in Angermanland, eastern Sweden, the Scandinavian glacio-isostatic uplift centre. Boreas, 33, 48-60. Oslo. ISSN 0300-9483.

Berné, S., Lericolais, G., Marsset, T., Bourillet, J.F., de Batist, M. (1998) Erosional shelf sand ridges and lowstand shorefaces: examples from tide and wave dominated environments of France. Journal of Sedimentary Research, 68, 540-555.

Bicket, A. (2011) (Ed.) Submerged Prehistory: Research in Context. Marine Aggregate Levy Sustainability Fund (MALSF) Science Monograph Series: No. 5.

Bingham, B., Foley, B., Singh, H., Camilli, R., Delaporta, K., Eustice, R., Mallios, A., Mindell, D., Roman, C., Sakellariou, D. (2010) Robotic Tools for Deep Water Archaeology: Surveying an Ancient Shipwreck with an Autonomous Underwater Vehicle Journal of Field Robotics, 1-16, DOI: 10.1002/rob.20350, 2010 Wiley Periodicals, Inc.

Bonifay, E. and Courtin, J. (1998) Les remplissages des grottes immergées de la région de Marseille. Dans Camps dir. – L'homme préhistorique et la mer, 120e congrès du CTHS, Aix-en-Provence, oct. 1995, Paris : éd. CTHS, 11-29.

Borst, W., Weerts, H., Vellinga, T., Otte, A. (2014) Monitoring programme for Maasvlakte 2, Part iv- Archaeological and palaeotological finds, Terra et Aqua, 135, 5-16.

Bose, M., Lüthgens, C., Lee, J.R., Rose, J. (2012) Quaternary glacitations of northern Europe. Quaternary Science Reviews. 44, 1-25.

Boulton, G. and Hagdorn, M. (2006) Glaciology of the British ice sheet during the last glacial cycle: form, flow, streams and lobes. Quaternary Science Reviews 25: 3359-3390.

Bourillet, J.-F., Reynaud, J.-Y., Baltzer, A. and Zaragosi, S. (2003), The 'Fleuve Manche': the submarine sedimentary features from the outer shelf to the deep-sea fans. J. Quaternary Sci., 18: 261-282. doi: 10.1002/jqs.757.

Boyce, J.I. and Reinhardt, E.G. (2004) Marine Magnetic Survey of a Submerged Roman Harbour, Caesarea Maritima, Israel. The International Journal of Nautical Archaeology, 33(1), 122-136.

Brossolo, L., Mascle, J., Loubtrieu, B. (2012) Morpho-Bathymetry of the Mediterraenan Sea, Map 1/4.000.000. 1st Edition, Published by the Commission for the Geological Map of the World (CGMW) and UNESCO).

Buynevich, I.V., Yanko-Hombach, V., Gilbert, A.S., Martin, R.E. (eds.) (2011) Geology and Geoarchaeology of the Black Sea Region: Beyond the Flood Hypothesis. Geological Society of America, Special Papers 473.

Cacho, I., Grimalt, J.O., Sierro, F.J., Shackleton, N.J., Canals, M. (2000) Evidence for enhanced Mediterranean thermohaline circulation during rapid climatic coolings, Earth Planet. Sci. Lett., 183, 417-429.

Çağatay, M. N., Eriş, K., Ryan, W.B.F., Sancar, Ü., Polonia, A., Akçer, S. Biltekin, D., Gasperini, L., Görür, N. Lericolais G., Bard, E. (2009) Late Pliestocene-Holocene evolution of the northern shelf of the Sea of Marmara. Marine Geology, 265: 87-100.

Çağatay, M.N. (1999) Geochemistry of the late Pleistocene-Holocene sediments of the Black Sea basin. In: S. Beşiktepe *et al.* (Eds.). Environmental degradation of the Black Sea: Challenges and Remedies. NATO Advanced Study Series, 9-22. Kluwer Academic Publishers.

Çağatay, M.N., Görür, N., Algan, O., Eastoe, C., Tchapalyga, A., Ongan, D., Kuhn, T., Kuşcu, İ. (2000) Last glacial-Holocene palaeoceanography of the Sea of Marmara: timing of the last connections with the Mediterranean and the Black Sea. Marine Geology, 167, 191-206.

Çağatay, M.N., Görür, N., Polonia, A., Demirbağ, E., Sakınç, M., Cormier, M.-H., Capotondi, L., McHugh, C., Emre, Ö., Eriş, K. (2003) Sealevel changes and depositional environments in the İzmit Gulf, eastern Marmara Sea, during the late glacial–Holocene period. Marine Geology, 202, 159-173.

Camidge, K., Holt, P., Johns, C., Randall, L., Schmidt, A. (2010) Developing Magnetometer Techniques to Identify Submerged Archaeological Sites. Theoretical Study Report. Cornwall Council Historic Environments Projects, 121pp.

Cavalli-Sforza, L.L., Menozzi, P., Piazza, A. (1994) The History and Geography of Human Genes. Princeton University Press.

Cavalli-Sforza, L.L., and Minch, E. (1997) Palaeolithic and Neolithic lineages in the European Mitochondrial gene pool. American Journal of Human genetics. 61. 247-254.

CIESM (2003) Human records of recent geological evolution in the Mediterranean Basin - historical and archaeological evidence. CIESM Workshop Monographs 24, 152pp.

Cicogna, N., Bianchi, C., Ferrari, G. (2003) Grotte marine d'Italia 50 anni di ricerche. Ministero dell'Ambiente, 289pp.

Cliquet, D., Coutard, S., Clet, M., Allix, J., Tessier, B., Lelong, F., Baltzer, A., Mear, Y., Poizot, E., Auguste, P., Alix, P., Olive, J., Guesnon, J. (2011) The Middle Palaeolithic underwater site of La Mondrée, Normandy, France. P. 111-128, in: Benjamin, J., Bonsall, C., Pickard, C., and Fischer, A. (ed.). Submerged Prehistory. Oxbow Books, Oxford. 338pp.

Clottes, J. and Courtin, J. (1994) La Grotte Cosquer. Peinturs et gravures de la caverne engloutie. Editions du Seuil, Paris, 197pp.

Clottes, J. and Courtin, J. (1994) The Cave beneath the sea. Harry N. Abrams. New York. 200pp.

Coles, B.J. (1998) Doggerland: speculative survey. Proceedings of the Prehsitoric Society. Vol. 64, 45-81.

Collina-Girard, J. (1992) Présentation d'une carte bathymétrique au 1/25 000 du précontinent marseillais (au large de la zone limitée par la grotte Cosquer et l'habitat préhistorique de Carry-le-Rouet). Géologie méditerranéenne, t. 19, n° 2, p. 77-87.

Collina-Girard, J. (2004) Prehistory and coastal karst area: Cosquer Cave and the "Calanques" of Marseille. Speleogenesis and Evolution of Karst Aquifers, 2 (2), 13pp. re-published from Karstologia 27, 1996, 27-40.

Council of Europe (1992) European Convention on the protection of the Archaeological heritage (Revised). ETS no. 143. Valetta. 6pp.

Crown Estates (2014) Offshore Renewables Protocol for Archaeological Discoveries: Palaeoenvironmental assessment of peat samples. Wessex Archaeology. 18pp.

Dalca, A.V., Ferrier, K.L., Mitrovica, J.X., Perron, J.T., Milne, G.A., Creveling, J.R. (2013) On postglacial sea level- III. Incorporating sediment redistribution, Geophysical Journal International, 194(1), 45-60.

Dardeau, M.R., Pollock, N.W., McDonald, C.M., Lang, M.A. (2012) The incidence of decompression illness in 10 years of scientific diving. Diving and Hyperbaric Medicine 42, 195-200.

Darlas, A., and Mihailovic, D. (ed.) (2008) The Palaeolithic of the Balkans. International Union of Prehistoric and Protohistoric Sciences. BAR International Series 1819, Archaeopress, Oxford. 116pp.

de Boer, B., van de Wal, R.S.W., Lourens, L.J., Bintanja, R., Reerink, T.J. (2013) A continuous simulation of global ice volume over the past 1 million years with 3-D ice-sheet models, Climate Dynamics, 41, 1365-1384.

Di Iorio, D. and Yüce, H. (1999) Observations of Mediterranean flow into the Black Sea. Journal of Geophysical Research 104:3091-3108.

Dix, J., Westley, K., Quinn, R. (2006) The Archaeology of the Continental Shelves: a Submerged Prehistory. English Heritage Report, London.

Dromgoole, S. (2013) Underwater Cultural Heritage and International law. Cambridge University Press, Cambridge, 436pp.

Dutton, A., Scicchitano, G. , Monaco, C., Desmarchelier, M., Antonioli, F., Lambeck, K., Esat, T., Fifield, K., McCulloch, A. (2009a) Uplift rates defined by U-series and 14C ages of serpulid-encrusted speleothems from submerged caves near Siracusa, Sicily (Italy), Quat. Geochronology. 4, 2-10.

Dutton, A., Antonioli, F., Bard E., M. Esat, T., Lambeck, K, McCulloch, M. (2009b) Phasing and amplitude of sea level and climate change during the penultimate interglacial. Nature Geosciences, 2, 355-359.

Efstratiou, N. (1985) Agios Petros, a neolithic site in the northern Sporades: Aegean Relationships during the neolithic of the 5th Millennium, BAR IS 241, Oxford.

Elefanti, P., E. Panagopoulou, P. Karkanas (2008) The transition from the Middle to the Upper Paleolithic in the Southern Balkans: the evidence from the Lakonis I Cave, Greece, Eurasian Prehistory 5, 85-95.

English Heritage (2014) Project 6205, National Heritage Protection Plan: 2D2 (Marine Exploitation): Development and delivery of a pilot marine geotechnical training course for archaeologists. 13pp.

Erİş, K., Ryan, W.B., Çağatay, M.N., Sancar, U.G., Lerıcolaıs, G., Ménot G., Bard, E. (2007) The timing and evolution of the post-glacial transgression across the Sea of Marmara shelf south of stanbul. Marine Geology 243, 57–76.

Eronen, M., Glückert, G., Hatakka, L., van de Plassche, O., van der Plicht, J., Rantala, P. (2001) Rates of Holocene isostatic uplift and relative sea-level lowering of the Baltic in SW Finland based on studies of isolation contacts . Boreas, Vol. 30, pp. 17–30. Oslo. ISSN 0300-9483.

Eshed, V., and Galili, E. (2013) Palaeodemography and health status of Mesolithic populations: finds from Atlit-Yam, a submerged site off the Israeli coast. p.106. in Under the Sea: Archaeology and palaeolandscapes. Szczecin, Poland. ISBN 978-83-7518-607-9. 145 pp.

European Commission (2013) Horizon 2020 Work Programme 2014-2015. 9. Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy 83 pp. Decision C (2013)8631 of 10 December 2013.

European Commission COM (2012) 473 final. Directorate General Maritime Affairs and Fisheries, Green Paper, Marine Knowledge 2020 from seabed mapping to ocean forecasting. 28 pp.

European Commission COM (2012) 494 final. Blue Growth: opportunities for marine and maritime sustainable growth.

European Commission COM (2013) 133 final. Establishing a framework for maritime spatial planning and integrated coastal management, 35 pp.

European Parliament (2013) A7-0209/2013, Report on Blue Growth: Enhancing sustainable growth in the EU's marine, maritime transport and tourism sectors (2012/2297(INI)).

European Union (2013) 2013/743/EU Council Decision of 3 December 2013 establishing the specific programme implementing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020) and repealing Decisions 2006/971/EC, 2006/972/EC, 2006/973/EC, 2006/974/EC and 2006/975/EC.

Eustice, R., Pizarro, O, Singh, H. (2008) Visually augmented navigation for autonomous underwater vehicles Oceanic Engineering, IEEE Journal of, 33(2).

Evans, A., Flatman, J., and Flemming, N.C. (ed.) (2014) Prehistoric Archaeology on the Continental Shelf: a Global Review. Springer, US. New York.

Evelpidou, N., Melini, D., Pirazzoli, P., Vassilopoulos, A. (2012a) Evidence of a recent rapid subsidence in the S-E Cyclades (Greece): an effect of the 1956 Amorgos earthquake? Cont Shelf Res. doi:10.1016/j.csr.2012.03.011

Evelpidou, N., Pavlopoulos, K., Vassilopoulos, A., Triantafyllou, M., Vouvalidis, K., Syrides, G. (2012b) Holocene palaeogeographical reconstruction of the western part of Naxos Island (Greece). Quat Int 266:81–93.

Faught, M. (2014) Remote Sensing, Target Identification and Testing for Submerged Prehistoric Sites in Florida: Process and Protocol in Underwater CRM Projects. In: Prehistoric Archaeology on the Continental Shelf. Springer New York.

Fenwick, V., Poudret-Barré, A., Momber, G. Demerre, I., Zeebroek, I., Bowens, A., Chatelin, C. (2012) Archaeological Atlas of the 2 Seas: Final Report 2009-2012. 80 pp. English Heritage.

Fischer, A. (1995) An entrance to the Mesolithic world below the ocean. Status of ten years' work on the Danish sea floor. In Fischer, A. (ed.): Man and Sea in the Mesolithic. Oxford Books, Oxford, 371-384.

Fischer, A. (ed.) (1995) Man and Sea in the Mesolithic. Coastal settlement above and below present sea level. Proceedings of the International Symposium, Kalundborg, Denmark 1993. Oxbow Monographs 53. Oxbow Books, England & The National Forest and Nature Agency, Ministry of Environment and Energy, Denmark.

Fischer, A. (2001) Coastal fishing in Stone Age Denmark – evidence from below and above the present sea level and from human bones. Atlantic, 54-69.

Fischer, A. (2011) Stone Age on the Continental Shelf. An eroding resource. In Benjamin, J., Bonsall, C., Fisher, A. & Pickard, C. (eds): Submerged Prehistory, 298–310. Oxbow Books, Oxford.

Fischer, A. and Bailey, G. (2015) (Eds). Submerged landscapes of the continental shelf. Vol.2: An atlas of submerged prehistoric archaeology. Wiley- Blackwell, Chichester.

Flemming, N.C. (1968) Derivation of Pleistocene Marine Chronology from the morphometry of erosion profiles. Journal of Geology, 76, 280-296.

Flemming, N.C. (1972) Relative chronology of submerged Pleistocene Marine erosion features in the Western Mediterranean. Journal of Geology, 80, 633-662.

Flemming, N.C. (1983) Preliminary geomorphological survey of an early Neolithic submerged site in the Sporadhes, N. Aegan. p. 233-268. in Masters, P.M. and Flemming, N.C. (eds). Quaternary Coastlines and Marine Archaeoloogy. Academic Press. London.

Flemming, N.C. (2002) The scope of Strategic Environmental Assessment of the North Sea areas SEA3 and SEA2 in regard to prehistoric archaeological remains. Department of Trade and Industry. Report TR_014.

Flemming, N.C., (Ed.) (2004) Submarine Prehistoric Archaeology of the North Sea. Council of British Archaeology. York .141 pp

Flemming, N.C.and Antonioli, F. (in press) Prehistoric archaeology, palaeontology, and climate change indicators from caves submerged by change of sea level. in: Campbell P. (ed) The Archaeology of Underwater Caves. Southampton: Highfield Press.

Flemming, N.C., Harff, J., Moura, D. (ed.) (2015) (Eds.) Submerged landscapes of the continental shelf. Vol.1. Quaternary Palaeo-environments of the European Continental Shelf: Environments for occupation and conditions for survival or destruction of submerged prehistoric deposits. Wiley-Blackwell. Chichester.

Gaffney, V., Thomson, K., Fitch, S. (2007) Mapping Doggerland: the Mesolithic Landscapes of the southern North sea. Archaeopress. Oxford. 131pp.

Gaffney, V., Fitch S. and Smith, D. (2009) Europe’s lost world: the rediscovery of Doggerland. CBA research report 1955 (York 2009)

Gagliano, S. M., Pearson, C. E., Weinstein, R. A., Wiseman, D. E., McClendon, C. M. (1982) Sedimentary studies of prehistoric archaeological sites: Criteria for the identification of submerged archaeological sites of the northern Gulf of Mexico continental shelf. Prepared for the U.S. Department of the Interior National Park Service, Division of State Plans and Grants, Contract No. C35003(79).

Gaillard, M.J. and Lemdahl, G. (1994) Early-Holocene coastal environments and climate in southeast Sweden: a reconstruction based on macrofossils from submarine deposits. The Holocene March 1994 4: 53-68.

Galanidou, N., Cole, J., Iliopoulos, G., McNabb, J. (2013) East meets West: the Middle Pleistocene site of Rodafnidia on Lesvos, Greece, Antiquity Project Gallery 087(336).

Galanidou, N. (2014) Archaeological survey on the Inner Ionian Sea Archipelago, In C. Smith (ed.), Encyclopaedia of Global Archaeology. Field Archaeology, New York, 3882-3888.

Galanidou, N. (In press) Advances in the Palaeolithic and Mesolithic archaeology of Greece for the new millennium, In Recent developments in the long-term archaeology of Greece, ed. J Bintliff. Pharos. The Journal of the Netherlands Institute at Athens, XX.1.

Galanidou, N., Athanassas, C., Cole, J., Iliopoulos, G., Katerinopoulos, A., Magganas, A., McNabb, J. (in press) The Acheulean site at Rodafnidia, Lisvori on Lesvos, Greece: part I. In: K. Harvati & M. Roksandic (eds), Human Evolution in the Southern Balkans, Springer.

Galili, E., Lernau, O., Zohar, I. (2004) Fishing and coastal adaptations at Atlit-Yam, a submerged PPNC Fishing village off the Carmel coast, Israel. 'Atiqot, 48, 1-34.

Galili, E., Weinstein-Evron, M., Hershkovitz, I., Gopher, A., Kislev, M., Lernau, O., Lolska-Horwitz, L., Lernau, H. (1993) Atlit-Yam: a prehistoric site on the sea floor off the Israeli coast. Journal of Field Archaeology 20, 133-157.

Gibbard, P. (2007) Palaeogeography: Europe cut adrift. Nature, 448(7151), 259-260.

Gibbard, P.L. (1988) The history of the great northwest European rivers during the last three million years. Philosophical Transactions of the Royal Society of London B(318), 559-602.

Gillham, J. (2011) Development of a field deployable underwater laser scanning system. PhD thesis, University of Waterloo, Canada, 116pp.

Gomez, N., Pollard, D., Mitrovica, J.X., Huybers, P., Clark, P.U. (2012) Evolution of a coupled marine ice sheet-sea level model, Journal of Geophysical Research: Earth Surface, 117, F01013.

Gomez, N., Pollard, D., Mitrovica, J.X.. (2013) A 3-D coupled ice sheet-sea level model applied to Antarctica through the last 40 ky, Earth Planet. Sci. Lett., 384, 88-99.

Gregory, D. (2012) Development of Tools and Techniques to Survey, Assess, Stabilise, Monitor and Preserve Underwater Archaeological Sites: SASMAP. In: M. Ioannides, D. Fritsch, J. Leissner, R. Davies, F. Remondino and R. Caffo (Eds.), Progress in Cultural Heritage Preservation. 4th International Conference, EuroMed 2012, Lemessos, Cyprus, 2012. Lecture Notes in Computer Science, Vol. 7616 (2012), 367-371.

Grøn, O., Dell' Anno, A., Hermand, J.-P. (2013) Investigations of deep, submerged Stone Age settlements covered by sea-floor sediments: preliminary methodological considerations. IEEE Explore: 978-1-4799-0002-2/13.

Gupta, S., Collier, J.S., Palmer-Felgate, A., Graeme, P. (2007) Catastrophic flooding origin of shelf valley systems in the English Channel, Nature, 448, 342-345.

Gutowski, M., Bull, J., Dix, J., Henstock, T., Hogarth, P., Hiller T., Leighton, T.G., White, P.R. (2008) Three-dimensional high-resolution acoustic imaging of the sub-seabed. Applied Acoustics, 69, 412-421.

Harff, J. and Lüth, F. (2007) SINCOS – Sinking Coasts. Geosphere, ecosphere and anthroposphere of the Holocene southern Baltic Sea. Preface. Bericht der Römisch–Germanischen Kommission 88: 9-14.

Harff, J., Hay, W.W., Tetzlaff, D.M. (2007) (eds.): Coastline Change – Interrelation of Climate and Geological Processes. The Geological Society of America, Special Paper 426.

Harff, J., Lemke, W., Lampe, R., Lüth, F., Lübke, H., Meyer, M., Tauber, F., Schmölcke, U. (2007) The Baltic Sea coast – a model of interrelations among geosphere, climate, and anthroposphere. In: Harff, J., Hay, W.W., Tetzlaff, D.M. (eds.) Coastline changes: interrelation of climate and geological processes. The Geological Society of America, Special Paper 426:133-142.

Hartz, S. and Lübke, H. (2006) New evidence for a chronostratigraphic division of the Ertebølle culture and the earliest Funnel Beaker culture on the southern Mecklenburg Bay. In: Kind, C.J. (ed.), After the Ice Age. Settlements, Subsistence and Social Development in the Mesolithic of Central Europe. Materialh. Arch. Baden-Württemberg 78 (Stuttgart 2006) 59-74.

Harvati, K., Darlas, A., Bailey, Sh.E., Rein, Th.R., El Zaatari, S., Fiorenza, L., Kullmer, O., Psathi, E. (2013) New Neanderthal remains from Mani peninsula, Southern Greece: The Kalamakia Middle Paleolithic cave site, Journal of Human Evolution 64(6), 1-14.

Harvati, K., Panagopoulou, E., Karkanas, P. (2003) First Neanderthal remains from Greece: the evidence from Lakonis, Journal of Human Evolution, 45, 465–473.

Harvati, K., Stringer, Ch., Karkanas, P. (2010) Multivariate analysis and classification of the Apidima 2 cranium from Mani, Southern Greece, Journal of Human Evolution, 60(2), 246-250.

Henderson, J., Gallou, C., Flemming, N., Spondylis, E. (2011) The Pavlopetri Underwater Archaeology Project: Investigating an ancient submerged town, in J. Benjamin, C. Bonsall, C. Pickard and A. Fischer (eds), Underwater Archaeology and the Submerged Prehistory of Europe. Oxbow Books, 207-18.

Henderson, J. (eds.) (2013) IKUWA 3: Beyond Boundaries. Proceedings of The 3rd International Congress on Underwater Archaeology, 9-12 July 2008, London. RGK Frankfurt, 491pp.

Henderson, J., Pizarro, O., Johnson-Roberson, M., Mahon, I. (2013) Mapping Submerged Archaeological Sites using Stereo-Vision Photogrammetry. IJNA, 42/ 2, 243-256.

Hermand, J.-P., Grøn, O., Asch, A., Ren, Q. (2011) Modelling flint acoustics for detection of submerged Stone Age sites. Proc. OCEANS '11 MTS/IEEE Kona Conf. (Oceans of Opportunity: International cooperation and partnership across the Pacific), Institute of Electrical and Electronics Engineers, IEEE, Sept. 2011.

Hijma, M.P., Cohen, K.M., Roebroeks, W., Westerhoff, W.E., Busschers, F.S. (2012) Pleistocene Rhine–Thames landscapes: geological background for hominin occupation of the southern North Sea region. Journal of Quaternary Science, 27, 17-39.

Hiscott, R.N., Aksu, A.E., Mudıe, P.J., Marret, F., Abrajano, T., Kamınski, M.A., Evans, J., akıro lu, A.I., Ya ar, D. (2007) A gradual drowning of the southwestern Black Sea shelf: evidence for a progressive rather than abrupt Holocene reconnection with the eastern Mediterranean Sea through the Marmara Sea Gateway. Quat. Int. Vol. 167-168, 19-34.

Hiscott, R.N., Aksu, A.E., Yasar, D., Kaminski, M.A., Mudie, P.J., Kostylev, V.E., McDonald, J.C., Isler, F.I., Lord, A.R. (2002) Deltas south of Bosphorus Strait record persistent Black Sea outflow to the Marmara sea since 10 ka. Mar. Geol., 190, 95-118.

Hombach, V., Gilbert, A.S., Panin, N., and Dolukhanov, P. (eds.) (2007) The Black Sea Flood Question: Changes in Coastline, Climate and Human Settlement. Springer, Dordrecht. 971pp.

Houmark-Nielsen, M. (2007) Extent and age of Middle and Late Pleistocene glaciations and periglacial episodes in southern Jylland, Denmark. Bulletin of the Geological Society of Denmark, 55 (1), 9-35.

Houmark-Nielsen, M. (2008) Testing OSL failures against a regional glaciation chronology from southern Scandinavia. Boreas, 37(4), 660-677.

Houmark-Nielsen, M. and Kjær, K.H. (2003) Southwest Scandinavia, 40-15 kaBP: palaeogeography and environmental change. J. Quaternary Sci., 18, 769–786.

Hubbard, A., Bradwell, T., Golledge, N., Hall, A., Patton, H., Sugden, D., Cooper, R., Stoker, M. (2009) Dynamic cycles, ice streams and their impact on the extent, chronology and deglaciation of the British–Irish ice sheet. Quaternary Science Reviews, 28 (7-8), 758-776.

Hublin, J-J., Weston, D., Gunz, P., Richards, M., Roebroeks, W., Glimmerveen, J., Anthonis, L. (2009) Out of the North Sea: the Zeeland Ridges Neandertal. Journal of Human Evolution, 57, 777-785. Doi:10.1016/j.jhevol.2009.09.001.

Huuse, M. and Lykke-Andersen, H. (2000) Overdeepened Quaternary valleys in the eastern Danish North Sea: morphology and origin. Quaternary Science Reviews, 19(12), 1233-1253.

IGC (2012) Proceedings of the 34th International Geological Congress 2012, Australian Geosceinces Council, 352 p. Canberra, Australia.

Johnson-Roberson, M., Pizarro, O., Williams, S., Mahon, I. (2010) Generation and Visualization of Large-Scale Three-Dimensional Reconstructions from Underwater Robotic Surveys. Journal of Field Robotics 27(1), 21-51.

Jöns, H. (2011) Settlement development in the shadow of coastal changes - case studies from the Baltic rim. In: J. Harff, S. Björck, P. Hoth (eds.) The Baltic Sea basin. Berlin-Heidelberg. 301-336.

Jöns, H. (2013) Von den Naturwissenschaften lernen? Überlegungen zu Beprobungs- und Untersuchungsstrategien in der archäologischen Siedlungsforschung. In: Sebastian Brather und Dirk L. Krausse (Ed.), Fundmassen. Innovative Strategien zur Auswertung frühmittelalterlicher Quellenbestände. Materialhefte zur Archäologie in Baden-Württemberg 97 (Stuttgart 2013), 65-74.

Jöns, H., Lübke, H., Lüth, F., Terberger, T. (2007) Prehistoric settlements and development of the regional economic area. Archaeological investigations along the Northeast-German Baltic Sea coast. Bericht der Römisch-Germanischen Kommission 88, 149-188.

Kapsimalis, V., Pavlakis, P. Poulos, S.E., Alexandri, S., Tziavos, C., Sioulas, A., Filippas, D., Lykousis, V. (2005) Internal structure and evolution of the Late Quaternary sequence in a shallow embayment: The Amvrakikos Gulf, NW Greece. Marine Geology 222-223, 399-418.

Keffer, T., Martinson, D.G., Corliss, B.H. (1988) The position of the Gulf Stream during Quaternary glaciations. Science 241, 440-442.

Klein, G., Bohlen, T., Forbriger, T. (2005) Acquisition and Inversion of Dispersive Seismic Waves in Shallow Marine Environments. Marine Geophysical Researches, 26.

Kontogianni, V.A., Tsoulos, N., Stiros, S. (2002) Coastal uplift, earthquakes and active faulting of Rhodes Island (Aegean Arc): Modeling based on geodetic inversion. Marine Geology 186: 299–317.

Koss, B. and Sieber, A. (2011) Development of a graphical Head-Up Display (HUD) for rebreather diving. Underwater Technology 29, 203-208.

Kuch, B., Buttazzo, G., Azzopardi, E., Sayer, M.D.J., Sieber, A. (2012) GPS diving computer for underwater tracking and mapping. Underwater Technology 30, 189-194.

Lambeck, K. (1995) Predicted shoreline models from rebound models. Journal of the Geological Society, 152: 437-448.

Lambeck, K. (1996) Glaciation and sea-level change for Ireland and the Irish Sea since Late Devensian/Midlandian time. J. Geol. Soc. Lond. 153, 853-872.

Lambeck, K. and Purcell, A. (2005) Sea-level change in the Mediterranean Sea since the LGM: model predictions for tectonically stable areas. Quaternary Science Reviews, 24, 1969-1988.

Lambeck, K. and Purcell, A. (2007) Palaeogeographic reconstructions of the Aegean for the past 20,000 years: Was Atlantis on Athens' doorstep? In The Atlantis Hypothesis: Searching for a Lost Land, (S. P. Papamarinopoulos, Ed.), Heliotopos Publications, 241-257.

Lambeck, K., and Purcell, A.P. (2001) Sea-Level Change in the Irish Sea since the Last Glacial Maximum: Constraints from isostatic modelling. J. Quat. Sci. 16, 497-506.

Lambeck, K., Antonioli, F., Anzidei, M., Ferranti, L., Leoni, G., Scicchitano, G., Silenzi, S. (2011) Sea level change along Italian coast during Holocene and a proiection for the future. Quaternary International, 232, 250-257.

Lambeck, K., Purcell, A., Zhao, J, Svensson, N.-O. (2010) The Scandinavian ice sheet: From MIS 4 to the end of the last glacial maximum. Boreas. 39(2), 410-435.

Lampe, R., Endtmann, E., Janke, W., Meyer, H., Lübke, H., Harff, J., Lemke, W. (2005) A New Relative Sea-Level Curve for the Wismar Bay, N-German Baltic Coast, Meyniana 57, 5-35.

Lampe, R., Naumann, M., Meyer, H., Janke, W and Ziekur, R. (2011) Holocene Evolution of the Southern Baltic Sea Coast and Interplay of Sea-Level Variation, Isostasy, Accommodation and Sediment Supply. In Harff, J., Björck, S. & Hoth, P. (eds): The Baltic Sea Basin, 233–251. Central and Eastern European Development Studies, Springer-Verlag, Berlin.

Leinikki, J., Kanerva, J., Panu Oulasvirta, P., Syvärant, J. (2013) Personal underwater tablets bring new possibilities to data collection, communication, geolocation and diver monitoring. In: Lang, M.A., Sayer, M.D.J. (editors) Proceedings of the 2013 AAUS/ESDP Curaçao Joint International Scientific Diving Symposium, October 24-27, 2013, Curaçao. Dauphin Island, AL: American Academy of Underwater Sciences. 163-166.

Lericolais, G. (1997) Evolution du fleuve Manche depuis l'oligocène : stratigraphie et géomorphologie d'une plateforme continentale en régime périglaciaire. PhD Thesis, Université Bordeaux I.

Lericolais, G. Popescu, I., Guichard, F. and Popescu, S.M. (2007a) A Black Sea lowstand at 8500 yr B.P. indicated by a relict coastal dune system at a depth of 90 m below sea level. In: J. Harff, W.W.Hay and D.M. Tetzlaff (Eds.), Coastline Changes: Interrelation of Climate and Geological Processes, GSA Books: Allen Press, Inc., Special Paper, 426, 171-188.

Lericolais, G., Popescu, I., Guichard, F., Popescu, S.M., Manolakakis, I. (2007b) Water-level fluctuations in the Black Sea since the Last Glacial Maximum. In Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement, 437-452.

Lericolais, G., Auffret, J.-P., Bourillet, J.-F. (2003) The Quaternary Channel River: seismic stratigraphy of its palaeo-valleys and deeps. Journal of Quaternary Science, 18(3-4): 245-60.

Lericolais, G., Bulois, C., Gillet, H., Guichard, F. (2009) High frequency sea level fluctuations recorded in the Black Sea since the LGM, Global and Planetary Change, 66, 65-75.

Lericolais, G., Guichard, F., Morigi, C., Popescu, I., Bulois, C., Gillet, H., Ryan, W.B.F. (2011) Assessment of Black Sea water-level fluctuastions since the lasst glacial maximum. Geological Society of America Special Paper 473, 1-18.

Lericolais, G., Popescu, I., Panin, N., Ryan, W.B.F. & Guichard, F. (2003) Last rapid flooding in the Black Sea. In: Uscinowicz, S. & Zachowicz, J. (eds), Rapid Transgressions Into Semi- enclosed Basins. IGCP 464. Polish Geological Institute, Gdansk, 39pp.

Linden,M., Möller, P., Björck, S., Sandgren, P. (2006) Holocene shore displacement and deglaciation chronology in Norrbotten, Sweden. Boreas, 35, 1-22.

Louwe Kooijmans, L.P. (1972) Mesolithic Bone and Antler Implements from the North Sea and the Netherlands. Ber. R.O.B. 2021, 27-73.

Lowag, J. (2010) Application of multi-transducer parametric sub-bottom profiler for three-dimensional archaeological investigations in shallow waters.

Lübke, H. (2002) Submarine Stone Age settlements as indicators of sea-level changes and the coastal evolution of the Wismar Bay area. In: R. Lampe (ed.) Holocene Evolution of the South-Western Baltic Coast – Geological, Archaeological and Palaeo-environmental Aspects. Field meeting of INQUA Subcommission V, 2002. Greifswalder Geographische Arbeiten 27 (Greifswald 2002), 203-210.

Lübke, H. (2005) Spät- und endmesolithische Küstensiedlungsplätze in der Wismarbucht – Neue Grabungsergebnisse zur Chronologie und Siedlungsweise, Bodendenkmalpflege in Mecklenburg-Vorpommern, Jahrbuch 52: 83-110.

Lübke, H., Schmölcke, U., Tauber, F. (2011) Mesolithic hunter-fishers in a changing world: a case study of submerged sites on theJäckelberg, Wismar Bay, northeastern Germany. In Benjamin, J.,Bonsall, C., Pickard, C., Fischer, A. (eds): Submerged Prehistory ,21-37. Oxbow Books, Oxford.

Lykousis, V. (2009) Sea-level changes and shelf break prograding sequences during the last 400 ka in the Aegean margins: subsidence rates and paleogeographic implications. Contenental Shelf Research, 29, 2037-2044.

Lykousis, V. and Anagnostou, Ch. (1994) Sedimentological and paleogeographic evolution of the Saronic Gulf during the Late Quaternary. Bull. Geol. Soc. Greece XXVIII/1, 501-510 (in Greek).

Lykousis, V., Sakellariou, D., Moretti, I., Kaberi, H. (2007) Late Quaternary basin evolution of the Gulf of Corinth: Sequence stratigrapgy, sedimentation, fault-slip and subsidence rates. Tectonophysics, 440, 29-51.

Lyras, G.A. and Van der Geer, A.A.AE. (2007) The Late Pliocene vertebrate fauna of Vatera (Lesvos Island, Greece), Cranium 24 (2), 11-24.

Mahon, I., Pizarro, O., Johnson-Roberson, M., Friedman, M., Williams, S., Henderson, J. (2011) Reconstructing Pavlopetri: Mapping the World's Oldest Submerged Town using Stereo-vision. IEEE International Conference on Robotics and Automation, 2315-2321.

Major, C.O. (2006) The co-evolution of Black Sea level and composition through the deglaciation and its paleoclimatic significance. Quart. Sci. Rev., 25, 2031-2047.

Major, C.O., Ryan, W. Lericolais, G. and Hajdas, I. (2002) Constraints on Black Sea outflow to the Sea of Marmara during the last glacial–interglacial transition, Marine Geology, 190: 19-34.

Marine Management Organisation (2013) Draft East Inshore and East Offshore Plans. MMO, Newcastle. 149pp.

Miettinen, A. (2004) Holocene sea-level changes and glacio-isostasy in the Gulf of Finland, Baltic Sea. Quaternary International, 120, 91-104.

Missiaen, T. and Feller, P. (2009) Detection of chemical munition buried below the seabed using seismic and magnetic techniques. First Break, 27, 69-74.

Mol, D., De Vos, J., Bakker, R., Van Geel, B., Glimmerveen, J., Van der Plicht, H., and Post, K. (2008) Mammoeten, neushoorns en andere dieren van de Noordzeebodem. Veen Magazines, Diemen 223.p.

Momber, G. (2011) Submerged landscape excavations in the Solent, southern Britain: climate change and cultural development. P. 85-98 in: Benjamin, J., Bonsall, C., Pickard, C., and Fischer, A. (eds.). Submerged Prehistory. Oxbow Books, Oxford. 338pp.

Moree, J.M. & M.M. Sier (ed.) (2014) Twintig meter diep! Mesolithicum in de Yangtzehaven – Maasvlakte te Rotterdam. Landschapsontwikkeling en bewoning in het Vroeg Holoceen. BOORrapporten 523. BOOR, Rotterdam, 361 pp. With digital annexes.

Müller, H. (2008) GEM-Shark - Electromagnetic subsurface profiler for coastal and shelf research, MARELEC (Stockholm) Conference Proceedings.

Okay, S., Jupinet, B., Lericolais, G., Cifci, G. and Morigi, C. (2011) Morphological and Stratigraphic Investigation of a Holocene Subaqueous Shelf Fan, North of the Istanbul Strait in the Black Sea - Turkish Journal of Earth Sciences, 20(3), 287-305.

Oppenheimer, S. (2006) The Origins of the British: A Genetic Detective Story. Constable, London. 534pp.

Parfitt, S.A., Ashton, N.M., Lewis, S.G., Abel, R.L., Coope, G.R., Field, M.H., Gale, R., Hoare, P.G., Larkin, N.R., Lewis, M.D., Karloukovski, V., Maher, B.A., Peglar, S.M., Preece, R.C., Whittaker, J.E., Stringer, C.B. (2010) Earliest Pleistocene human occupation at the edge of the boreal zone in Northwest Europe. Nature 466: 229–233.

Pasquinucci, M., Pranzini, E., Silenzi, S. (2004) Evolucion Paleoambiental de los Puertos y Fondeaderos antiguos en el Mediterràneo occidental. I Seminario ANSER, Variazioni del livello marino ed evoluzioni della costa toscana in epoca storica: opportunità di porti e approdi, vol. I, 87-102.

Pastol, Y. (2011) Use of Airborne LiDAR Bathymetry for Coastal Hydrographic Surveying: The French Experience. Journal of Costal Research, 62, 6-18.

Pe'eri, S., Morgan, L., Philpot, W., Armstrong, A. (2011) Land-Water Interface Resolved from Airborne LiDAR Bathymetry (ALB) Waveforms. Journal of Costal Research, 62, 75-85.

Pedersen, L., Fischer, A., Aaby B. (eds.) (1997). The Danish Storebælt since the Ice Age - man, sea and forest. The Storebælt Publications.

Peeters, H., Murphy, P., Flemming, N.C. (2009) (eds). North Sea Prehistory research and management framework (NSPRMF). English Heritage and Rijksdienst voor het Cultureel Erfgoed, Amersfoort. 40pp.

Peeters, J.H.M. and Cohen, K.M. (2014) Introduction to North Sea submerged landscapes and prehistory. Netherlands Journal of Geosciences 93, 3-5.

Peltier, W.R., Shennan, I., Drummond, R., Horton, B. (2002) On the postglacial isostatic adjustment of the British Isles and the shallow viscoelastic structure of the Earth. Geophysical Journal International 148(3): 443-75.

Perissoratis, C., Piper, D.J.W., Lykousis, V. (1993) Late Quaternary sedimentation in the Gulf of Corinth: the e ects ofMarine-Lake fluctuations driven byeustatic sea level changes. In: Special Publication Dedicated to Prof. A. Panagos.Nat. Tech. Univ. of Athens, 693-744.

Pettitt, P. (2008) The British Upper Palaeolithic. In Pollard, J. (ed). Prehistoric Britain: Blackwell studies in global archaeology 11. Blackwell Publishing. Oxford.

Pinardi, N. and Masetti, E. (2000) Variability of the large scale general circulation of the Mediterranean Sea from observations and modelling: a review. Palaeogeography, Palaeoclimatology, Palaeoecology 158: 153-173.

Pirazzoli, P.A., Montaggioni, L.F., Saliege, J.F., Segonzac, G., Thommeret, Y., Vergnaud-Grazzini, C. (1989) Crustal block movements from Holocene shorelines: Rhodes Island (Greece). Tectonophysics, 170, 89-114.

Pitulko, V.V., Nikolsky, P.A., Girya, E.Yu., Basilyan, A.E., Tumskoy, V.E., Koulakov, S.A., Astakhov, S.N., Pavlova, E.Yu., Anisimov, M.A. (2004) The Yana RHS Site: Humans in the Arctic Before the Last Glacial Maximum. Science 303 (5654), 52-56.

Pizarro, O., Eustice, R.M., Singh, H. (2009) Large Area 3-D Reconstructions From Underwater Optical Surveys. Oceanic Engineering, IEEE Journal of, 34(2), 150-169.

Psychoyos, O. (1988) Déplacement de la ligne de rivage et sites archéologiques dans les régions côtières de la Mer Egée, au Néolithique et a l'age du Bronze. Paul Astroms Forlag, Jonsered.

Quinn, R., Bell, T., Edwards, R, O'Sullivan, A., Plets, R, Westley, K., Forsythe, W. (2008) A research strategy for mapping the archaeological potential of the seabed - Ireland and Newfoundland 2008. Submerged Landscapes Archaeological Network.

Ransley, J., Sturt, F., Dix, J., Adams, J., Blue, L. (2013) People and the Sea: a maritime Archaeological Research Agenda for England. Council for British Archaeology. 250pp.

Rasmussen, M., Anzick, S. L., Waters, M. R., Skoglund, P. *et al.* (2014) The genome of a Late Pleistocene human from a Clovis burial site in western Montana. Nature 506, 225-229.

Reid, C. (1913) Submerged Forests. Oxford. 129pp.

Ren, Q.-Y, Grøn, O., Hermand, J.-P. (2012) On the in-situ detection of flint for underwater Stone Age archaeology.

Richards, D.A., Smart, P.L., Edwards, R.L. (1994) Maximum sea levels for the last glacial period from U-series ages of submerged speleothems. Nature, 367(6461) 357-360.

Richter, D.K., Anagnostou, Ch., Lykousis, V. (1993) Aragonitishe whiting-Ablagerungen in Plio-/Pleistozaenen Mergelsequenzen bei Korinth (Griechenland). Journal Geology Paleontology Heft 6, 675-688.

Rijsdijk, K.F., Hengl, T., Norder, S., Otto, R., Emerson, B.C., Ávila S.P., López, H., van Loon, E.E., Tjørve, E., Fernández-Palacios, J.M. (2014) Quantifying surface-area changes of volcanic islands driven by Pleistocene sea-level cycles: biogeographical implications for the Macaronesian archipelagos, 41(7), 1242-1254.

Rohling, E.J., Grant, K., Bolshaw, M., Roberts, A.P., Siddall, M., Hemleben, C., Kucera, M. (2009) Antarctic temperature and global sea level closely coupled over the past five glacial cycles. Nature Geoscience, 2, 500-504.

Rohling, E.J., Hayes, A., Kroon, D., De Rijk, S., Zachariasse, W.J. (1998) Abrupt cold spells in the Late Quaternary NW Mediterranean. Paleoceanography, 13(4), 316-322.

Rosentau, A., Muru, M., Kriiska, A., Subetto, D.A., Vassiljev, J.,Hang, T., Gerassimov, D., Nordqvist, K., Ludikova, A., Lõugas, L., Raig, H., Kihno, K., Aunap, R., Letyka, N. (2013) Stone Age settlement and Holocene shore displacement in the Narva-Luga Klint Bay area, eastern Gulf of Finland. Boreas: DOI:10.1111/bor.12004.

Rosentau, A., Veski, S., Kriiska, A., Aunap, R., Vassiljev, J., Saarse, L., Hang, T., Heinsalu, A., Oja, T. (2011) Palaeogeographic model for the SW Estonian coastal zone of the Baltic Sea. In Harff, J., Björck, S., Hoth, P. (eds): The Baltic Sea Basin, 165-188. Central and Eastern European Development Studies, Springer-Verlag, Berlin.

Rugenstein, M., Stocchi, P., von der Heydt, A., Dijkstra, H., Brinkhuis, H. (2014) Emplacement of Antarctic ice sheet mass affects circumpolar ocean flow, Global and Planetary Change, 118, 16-24.

Ryan, W.B.F., Major C., Lericolais, G., Goldstein, S.L. (2003) Catastrophic Flooding Of the Black Sea. Annu. Rev. Earth Planet. Sci. 31, 525-554.

Sakellariou, D., Lykousis, V., Alexandri, S., Kaberi, H., Rousakis, G., Nomikou, P., Georgiou, P., Ballas, D. (2007a) Faulting, seismic-stratigraphic architecture and Late Quaternary evolution of the Gulf of Alkyonides basin – East Gulf of Corinth, Central Greece. Basin Research, 19/2, 273-295.

Sakellariou, D., Rousakis, G., Kaberi, H., Kapsimalis, V., Georgiou, P., Kanellopoulos, Th., Lykousis, V. (2007b) Tectono-sedimentary structure and late quaternary evolution of the north Evia gulf basin, Central Greece: preliminary results. Bulletin of the Geological Society of Greece vol. XXXVII/1, 451-462.

Sakellariou, D., Rousakis, G., Maroulakis, S., Georgiou, P., Kalogirou, S., Henderson, J., Gallou, Ch., Spondylis, I., Pizzaro, O., Hogarth, P., Flemming, N. (2011) The submerged city of Pavlopetri. In Poseidons Reich XVI, (DEGUWA 2011), Heidelberg, February 18-20, 2011.

Sayer, M.D.J. (2007) Scientific diving: a bibliographic analysis of underwater research supported by SCUBA diving, 1995-2006. Underwater Technology 27, 75-94.

Schmölcke U. and Jöns, H. (2013) Livestock in Early Medieval Ports of Trade on the Baltic Sea: The Emporium Reric and other Northern German Sites. In: Kleingartner, S., Newfield, T. P., Rossignol, S., u. Wehner, D. (eds.), Landscapes and Societies in Medieval Europe East of the Elbe: Interactions between Environmental Settings and Cultural Transformations. Papers in Medieval Studies 23. Toronto 2013. 54-72.

SEAS-ERA (2013) Towards a strategic research agenda/ Marine Research Plan for the European Atlantic Sea Basin (FP7 D6.1.1), 44pp.

Shackleton, N.J. and Opdyke, N.D. (1977) Oxygen isoptope and palaeomagnetic evidence for early Northern Hemisphere glaciation. Nature 270, 216-219.

Shennan, I., Bradley, S., Milne, G., Brooks, A., Bassett, S., Hamilton, S. (2006) Relative sea-level changes, glacial isostatic modelling and ice-sheet reconstructions from the British Isles since the Last Glacial Maximum. J. Quaternary Sci., 21: 585–599. doi: 10.1002/jqs.1049.

Shennan, I., Lambeck, K., Flather, R., Horton, B., McArthur, J., Innes, J., Lloyd, J., Rutherford, M., Wingfield, R. (2000) Modelling western North Sea paleogrpgraphies and tidal changes during the Holocene, 299-319. in: Shennan I., and Andrews J. (ed.). Holocene Land-Ocean Interaction and Environmental Change around the North Sea. Geological Society, London. Special Publication 166. 326pp.

Sieber, A., Kuch, B., Enoksson, P., Stoianova-Sieber, M. (2012) Development of a head-up displayed diving computer capability for full face masks. Underwater Technology 30, 195-199.

Smith, D.E., Cullingford, R.A., Mighall, T.M., Jordan, J.T., Fretwell, P.T. (2007) Holocene relative sea level changes in a glacio-isostatic area: New data from south-west Scotland, United Kingdom. Marine Geology, 242 (1-3), 5-26.

Sordinas, A. (1983) Quaternary shorelines in the region of Corfu and adjacent islets, western Greece, in: Masters P. and Flemming, N.C. (ed.). Quaternary Coastlines and Marine Archaeology: Towards the prehistory of land bridges and continental shelves, Academic Press. London: 335-344.

Spada, G. and Stocchi, P. (2007) SELEN: A Fortran 90 program for solving the "sea-level equation", Computers & Geosciences 33(4), 538-562.

Stocchi, P. *et al.* (2013) Relative sea-level rise around East Antarctica during Oligocene glaciation, Nature Geoscience 6, 380-384.

Stringer, C. (2006) Homo Britannicus: the incredible story of human life in Britain. Allen Lane, London, 319 pages. ISBN-13: 978-0-713-99795-8.

Svendsen, J.I., Alexanderson, H., and Astakhov, V.I. (2004) Late Quaternary ice sheet history of northern Eurasia. Quaternary Science Review 23, 1229-1271.

Tauber, F. (2007) Seafloor exploration with sidescan sonar for geo-archaeological investigations. In: Bericht der Römisch-Germanischen Kommission 88, 67-79.

Tappin, D R., Pearce, B., Fitch, S., Dove, D., Gearey, B., Hill, J M., Chambers, C., Bates, R., Pinnion, J., Diaz Doce, D., Green, M., Gallyot, J., Georgiou, L., Brutto, D., Marzialetti, S., Hopla, E., Ramsay, E., Fielding, H. (2011) The Humber Regional Environmental Characterisation. British Geological Survey Open Report OR/10/54. 357pp.

Toucanne, S., Zaragosi, S., Bourillet, J.F., Cremer, M., Eynaud, F., Van Vliet-Lanoë, B., Penaud, A., Fontanier, C., Turon, J.L., Cortijo, E., Gibbard, P.L. (2009) Timing of massive 'Fleuve Manche' discharges over the last 350 kyr: insights into the European ice-sheet oscillations and the European drainage network from MIS 10 to 2. Quaternary Science Reviews, 28, 1238-1256.

TRC Environmental Corporation (2012) Inventory and analysis of archaeological site occurrence on the Atlantic outer continental shelf. U.S. Dept. of the Interior, Bureau of Ocean Energy, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEM 2012-008. 324pp.

UNCLOS Article 76 conshelf definition. United Nations (1983) United Nations Convention on the Law of the Sea (1982). C. Helm. London. 224pp. ISBN 013247551.

UNESCO (2001) The UNESCO Convention on the Protection of the Underwater Cultural Heritage. UNESCO General Conference 31 C.

Uścinowicz, Sz. (2006) A relative sea-level curve for the Polish Southern Baltic Sea. Quaternary International 145/146, 86-105.

Valetta Convention, see Council of Europe (1992).

Van Andel, T.H. (1989) Late Quaternary Sea level Changes and Archaeology. Antiquity, 63, 733-745.

Van Ginkel, E., Reumer, j., Van der Valk, B., (2014) Schatten van het Mammoetstrand. Over speuren in grondlagen, opgraven onder water en vissen naar fossielen. Havenbedrijf Rotterdam, Projectorganisatie Maasvlakte 2, 216 pp. Rotterdam.

Veski, S., Heinsalu, A., Klassen, V., Kriiska, A., Lõugas, L., Poska, A., Saluäär, U. (2005) Early Holocene coastal settlement and palaeoenvironment on the shore of the Baltic Sea at Pärnu, southwestern Estonia. Quaternary International 130, 75-85.

Waters, M.R. (1992) Principles of Geoarchaeology: A North American perspective. Tucson: The University of Arizona Press.

Weerts, H.J.T., Otte, A., Smit, B., Vos, P., Schiltmans, D., Waldus, W., Borst, W. (2012) Finding the Needle in the Haystack by Using Knowledge of Mesolithic Human Adaptation in a Drowning Delta. In: Bebermeier, W., Hebenstreit, H., Kaiser, E. & Krause, J. (eds.), Landscape Archaeology. Proceedings of the International Conference Held in Berlin, 6th-8th June 2012. eTopoi Journal for Ancient Studies, Special Volume 3: 17-24.

Wehner, D. (ed.) (2013) Landscapes and Societies in Medieval Europe East of the Elbe: Interactions between Environmental Settings and Cultural Transformations. Papers in Medieval Studies 23 (Toronto 2013) 54-72.

Wessex Archaeology (2011) Seabed Prehistory: Site Evaluation Techniques (Area 240) Synthesis. 71pp.

Wessex Archaeology (2014) Dredging and Port Construction: Interactions with features of archaeological or heritage interest. A PIANC Guidance Document. 54 pp.

Yim, W.W.S., Rogers, J., Tovey, N.K. (eds.) (2002) Continental Shelves in the Quaternary: IGCP 396. Quaternary International, 92, 1-112.

Yu, S.-Y., Berglund, B. E., Sandgren, P., Lambeck, K. (2007) Evidence for a rapid sea-level rise 7600 yr ago. Geology, 35, 891-894.

Zulkus, V. and Girininkas, A. (eds.) (2012) The coasts of the Baltic Sea 10 000 years ago. Klaipeda University. 55pp. (in Lithuanian with English summary) ISBN 978-9955-18-707-3.

List of acronyms

AESD	Advanced European Scientific Diver
AMH	Anatomically Modern Humans
AMS	Accelerated Mass Spectrometry
AUV	Autonomous Underwater Vehicle
BGR	German Federal Institute for Geosciences and Natural Resources
BOOR	Rotterdam Archaeological Department
BP	years before present
BSB	Baltic Sea Basin
BSBD	Baltic Sea Bathymetry Database
CGMW	Commission for the Geological Map of the World
CIESM	The Mediterranean Science Commission
COST	European Cooperation in Science and Technology
DFG	German Research Foundation
DTM	Digital Terrain Models
EAC	Europae Archaeologiae Consilium/ European Archaeological Council
EC DG MARE	European Commission Directorate-General for Maritime Affairs and Fisheries
EAA	European Association of Archaeologists
EEZ	Exclusive Economic Zones
EIA	Environmental Impact Assessment
EMB	European Marine Board
EMODnet	European Marine Observation and Data Network
ESD	European Scientific Diver
ESDP	European Scientific Diving Panel
EU	European Union
EuDA	European Dredging Association

EUROSION Project	A European initiative for sustainable coastal erosion management
FP7 SASMAP	Development of Tools and Techniques to Survey, Assess, Stabilise, Monitor and Preserve Underwater Archaeological Sites
FP7 SEAS-ERA	Towards Integrated Marine Research Strategy and Programmes, 7th Framework Programme
GIA	Glacial Hydro-Isostatic Adjustment
HOV	Human Operated Vehicles
IBCM	International Bathymetric Chart of the Mediterranean
ICT	Information and Communications Technology
ICZM	Integrated Coastal Zone Management
IHO	International Hydrographic Organization
INQUA	International Union for Quaternary Science
INTERREG IIIA	EC Trans-frontier Programme on cross-border cooperation
IOC	Intergovernmental Oceanographic Commission
IQuaME 2500	International Quaternary Map of Europe 1:2,500,000
JPI	Joint Programming Initiative
LBL	Long baseline
LGM	Last Glacial Maximum
MACHU	Managing under water cultural heritage
MODEG	Marine Observation and Data Expert Group
MoSS Project	Monitoring, safeguarding and visualization of North European shipwreck sites
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning
NSPRMF	North Sea Prehistory and Management Framework
ORPAD	Offshore Renewable Protocol for Archaeological Discoveries
OSL	Optical Stimulated Luminescence dating

OSL	Optically Stimulated Luminescence
PIANC	World Association for Waterborne Transport Infrastructure
RCE	The Netherlands Cultural Heritage Agency
RFO	Research Funding Organization
ROV	Remotely Operated Vehicles
RSL	Relative Sea Level
SBL	Short baseline
SC	Societal Challenges
SIS	Scandinavian Ice Sheet
SLAM	Simultaneous Localization and Mapping
SME	Small-Medium Enterprise
SoM	Sea of Marmara
SPLASHCOS Action	Submerged Prehistoric Landscapes and Archaeology of the Continental Shelf
TEN-T	EU Trans-European Transport Network
ULS	Underwater Laser Scanning
UNCLOS	United Nations Convention on the Law of the Sea
USBL	Ultra-short baseline
VAN	Visually Augmented Navigation
WG SUBLAND	Working Group on Submerged Landscape
WMS	Web Map Services
WoodCultHer project	Wood Science for Conservation of Cultural Heritage

Annex 1

Affiliations of contributing authors

Nicholas Flemming, National Oceanography Centre, UK (WG Chair)

M. Namık Çağatay, Istanbul Technical University, Turkey

Nena Galanidou, University of Crete, Greece

Hauke Jöns, Lower Saxony Institute for Historical Coastal Research, Germany

Francesco Latino Chiocci, University of Rome La Sapienza, Italy

Gilles Lericolais, French Research Institute for Exploration of the Sea (Ifremer), France

Tine Missiaen, Ghent University, Belgium

Fionnbarr Moore, National Monuments Service Department of Arts, Heritage and Gaeltacht, Ireland

Alar Rosentau, University of Tartu, Estonia

Dimitris Sakellariou, Hellenic Centre for Marine Research, Greece

Birgitte Skar, Norwegian University of Science and Technology, Norway

Alan Stevenson, British Geological Survey, UK

Henk Weerts, Cultural Heritage Agency, Ministry of Education, Culture and Science, The Netherlands

Annex 2

List of Deukalion Planning Group and Underwater Cultural Heritage Working Group of the European Archaeological Council

Deukalion Planning Group

Geoff Bailey (UK, co-Chair)

Miquel Canals (Spain)

Francesco Latino Chiocci (Italy)

Katerina Dellaporta (Greece)

Justin Dix (UK)

Anders Fischer (Denmark)

Nic Flemming (UK)

Vince Gaffney (UK)

Ole Grøn (Denmark)

Jostein Gundersen (Norway)

Jan Harff (Germany)

Gilles Lericolais (France)

Friedrich Lueth (Germany)

Tine Missiaen (Belgium)

Garry Momber (UK)

Dimitris Sakellariou (Greece, co-Chair)

Julie Sutchell (UK)

European Archaeological Council Underwater Cultural Heritage WG

Fionnbarr Moore (Chair) Underwater Archaeology Unit, National Monuments Service, Ireland

Francisco J. S. Alves, Centro Nacional de Arqueologia Náutica e Subaquática, Portugal

Jørgen Dencker, Maritime Archaeology, Viking Ship Museum, Denmark

Michel L'Hour, Département des Recherches Archéologiques Subaquatiques et Sous-Marines, France

Friedrich Luth, German Archaeological Institute, Germany

Jasen Mesic, Ministry of Culture, Republic of Croatia

Andrea D.C. Otte-Klomp, Maritiem Erfgoed, Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten, Netherlands

Ian Oxley, English Heritage, United Kingdom

Marnix Pieters, Maritime Archaeology and Heritage Afloat Unit, Flemish Heritage Institute (VIOE), Belgium

Iwona Pomian, Department of Underwater Archaeology, Polish Maritime Museum, Poland

Maili Roio, National Heritage Board, Tallinn, Estonia

Helmut Schlichtherle, Regierungspräsidium Stuttgart, Landesamt für Denkmalpflege, Germany

Fredrik Skoglund, Department of Archaeology and Cultural History, Museum of Natural History and Archaeology, Trondheim, Norway

Attila Tóth, Ministry of Interior, Hungary

Björn Varenius, National Maritime Museums, Stockholm, Sweden

Stefan Wessman, Maritime Archaeology Unit, National Board of Antiquities, Helsinki, Finland

Claus Wolf, Regierungspräsidium Stuttgart, Landesamt für Denkmalpflege Baden-Württemberg, Germany

Annex 3

Response to a stakeholder consultation of Horizon 2020/ Societal Challenge 5 "Climate action, environment, resource efficiency and raw materials"

(This response was submitted on 16 June 2014 to the European Commission.)

This stakeholder consultation is the response on behalf of an organization, the European Marine Board (EMB), based on one of its current activities of an expert working group "Submerged Landscape and Prehistory Research" (WG SUBLAND) endorsed by the EMB.

Contacts

Dr. Nicholas Flemming (EMB WG SUBLAND Chair) nflemming@sheetsheath.co.uk
Dr. Nan-Chin Chu (EMB Secretariat) nchu@esf.org

Position of the European Marine Board

The European Marine Board (EMB) is a pan-European forum for its member organizations to develop common priorities, to advance marine research and to bridge the gap between science and policy, in order to meet future marine science and societal challenges and opportunities. In 2014, EMB has 36 Member Organizations (MOs) comprised of national research funding and research performing organizations, including university networks, across Europe.

During the last one million years, the European landmass was periodically fluctuating in area, sometimes making it 40%[41] larger than at present due to the global volumes of water locked up in ice caps. This now submerged landmass holds valuable information on the long-term history of human settlements during several episodes of migration, abandonment and reoccupation, which shaped the European landscape, the environment and its population. Cultural heritage assets are unique and are a major driver of societal cohesion, identity and well-being[42]. The Council of the European Union recently adopted conclusions on **cultural heritage as a strategic resource for a sustainable Europe**[43] and invited the European Commission to further support networking and promoting projects aimed at fostering sustainable management of cultural heritage.

With increasing offshore economic activities, these submerged historical records are under threat. The European Marine Board recognizes the importance of **Continental Shelf Prehistoric Research**, a new trans-disciplinary domain **linking the analysis of climate/ sea level change, environmental conditions and prehistoric archaeology.**

In order to address the interdisciplinary nature of the subject, the European Marine Board launched an expert working group on submerged landscape and prehistoric research (WG SUBLAND)[44] (Sept. 2013 to Oct. 2014), gathering experts from the MOs of the EMB, Europae Archaeologiae Consilium/ European Archaeological Council (EAC) and a network established by the COST Action SPLASHCOS[45].

[41] For example, at the last glacial maximum (LGM), the European land area was increased by 3.2 million km², with some places having a lowered sea level by about 120m-150m as a result.

[42] EU Council Decisions 2013/743/EU, OJ L347, 20.12.2013, p. 1022.

[43] EU Council Conclusions on cultural heritage as a strategic resource for a sustainable Europe at Education, Youth, Culture and Sport Council meeting, Brussels, 20 May 2014.

[44] http://www.marineboard.eu/submerged-landscapes Flemming NC, Çağatay MN, Chiocci FL, Galanidou N, Jöns H, Lericolais G, Missiaen T, Moore F, Rosentau A, Sakellariou D, Skar B, Stevenson A, Weerts H (in prep.) Land beneath the waves: Submerged landscapes and sea level change--A joint geoscience-humanities strategy for European Continental Shelf Prehistoric Research, Chu NC and McDonough N (Eds.) Position paper 21 of the European Marine Board, Ostend, Belgium.

[45] COST Action TD0902 (2009-2013) http://www.splashcos.org/

The Working Group will deliver its position paper in October 2014 with the main objectives of:

- Recognizing the importance of Continental Shelf Prehistoric Research and the implications for future climate change impact;
- Integrating interdisciplinary knowledge in underwater research, especially in relation to prehistoric social change, and propose a way ahead for collaborative multidisciplinary research, including improved technology, training and funding resources;
- Highlighting this knowledge on prehistoric human-marine interaction;
- Formulating recommendations to foster processes with socio-economic benefits, e.g. Marine Spatial Planning (MSP), and to address societal challenges related to EC Climate Action (DG CLIMA) and Blue Growth (DG MARE).

Europe is amongst the world leaders in Continental Shelf Prehistoric Research, and we need to consolidate and expand that advantage.

*Please consider the following questions, citing any available evidence such as **foresight** and other assessments of **research and innovation trends** and **market opportunities**:*

1) What is the biggest challenge in the field concerned which requires immediate action under the next Work Programme? Which related innovation aspects could reach market deployment within 5-7 years?

Continental Shelf Prehistoric Research is a new trans-disciplinary domain **linking the analysis of climate/ sea level change, environmental conditions and the prehistoric archaeology** of people who lived and migrated on the ancient coastal plains. These records on the now submerged continental shelves can be preserved during seawater transgression.

With **increasing offshore activities** and initiatives such as the EC Blue Growth policy[46] and European sea basins action plans[47], it is both timely and crucial to recognize Continental Shelf Prehistoric Research in order to mitigate damage from exploitation, increase site prediction and discovery through technological advancement and reduce the uncertainties of offshore operators due to site discovery by collaborating with industrial stakeholders. In this way, the management of cultural heritage assets will become more efficient and sustainable. The European Marine Board, through its Working Group SUBLAND, identifies the following challenges which require immediate action under the next Work Programme that will reach market deployment by 2020:

I. **Training and Education** to prospect underwater cultural heritage: Continental Shelf Prehistoric Research requires a continued structure with educational and training supports, and interaction with other relevant research communities[48]. This is in line with the target of the Erasmus+ *Knowledge Alliance*[49] to boost innovation and stimulate the flow and exchange of knowledge between higher education and enterprises. This will also encourage *Capacity Building* and *Sector Skill Alliance* to tackle skill gaps for sustainable development.

[46] EC COM(2014) 254/2 (13.5.2014) http://ec.europa.eu/maritimeaffairs/policy/blue_growth/
[47] EC COM(2013) 279 (13.5.2013) http://ec.europa.eu/maritimeaffairs/policy/sea_basins/atlantic_ocean/index_en.htm
[48] For example: palaeoclimatology, climate modeling, geophysical engineering, geochemistry and genetics.
[49] EU OJ L347, 20.12.2013, p. 58. Eurasmus+: http://ec.europa.eu/programmes/erasmus-plus/index_en.htm

II. **Access to technology and data:** Research infrastructure use in cultural heritage management was highlighted at the last International Conference on Research Infrastructure (ICRI, Athens; April 2014)[50]. Most of the relevant offshore prospecting technology has been developed and managed by the marine science community and offshore industries. It is strongly encouraged that this infrastructure and technology expertise is shared. Likewise, long-term restructuring and access to data with no commercial value is required to develop datasets at European level. EMODnet[51], part of the EU's open data initiative, aims to make marine data more accessible, interoperable and useful to end-users. The community of Continental Shelf Prehistoric Research recommends that underwater archaeological data be included in such data initiatives. It is only through open access to data and technology that the required inter-disciplinary integration of both the marine science community and offshore industries will be achieved.

III. **Industrial partnership** for a coordinated collaboration and technology advancement: It is an important challenge to promote collaboration between offshore industries, cultural heritage agencies and research institutes to excel research and to reduce the cost and complexity of enforcing conditions of licensing. The discovery of submerged prehistoric sites requires improved technology, such as acoustic systems, diving tools and the application of remotely operated vehicles (ROVs). By teaming up with industrial stakeholders through public-private partnerships, further technology development can be stimulated.

IV. **Multi-stakeholder mechanism:** Operational costs can be kept to a minimum by combining the initial surveys necessary for Continental Shelf Prehistoric Research with those already required for environmental assessment. The logical and administrative links between ecosystem management, nature-based solutions, and cultural heritage have been recommended in the SC5 Advisory Group report[52]. Governance with a multi-stakeholder model from environmental, industrial and academic sectors will improve the efficiency of site management.

2) What are the key assumptions underpinning the development of these areas (research & innovation, demand side and consumer behavior, citizens' and civil society's concerns and expectations)?

Underwater cultural heritage has always held the public's interest, with a number of TV programs and frequent articles in the popular press. The media attraction of underwater cultural heritage demonstrates citizens' interest in the history of human societies. Supporting Continental Shelf Prehistoric Research directly reflects modern society's expectations in answering questions about early human migrations, origins of seafaring, exploitation of marine resources and response to sea level change. Already over 2,500 submerged prehistoric sites have been catalogued in European seas, mostly dating from 5,000-20,000 years old, with a few in the range 20,000 to 300,000 years old. Organic archaeological materials can be found underwater which are seldom found in dry-land sites of the same age. Seabed prehistory is a substantial part of European cultural heritage, and is covered by treaties and international agreements. The development of Continental Shelf Prehistoric Research will integrate areas in Social Sciences and Humanities (SSH).

[50]http://www.icri2014.eu/

[51]European Marine Observation and Data Network (EMODnet) http://www.emodnet.eu/

[52]First Report of the Horizon 2020 Advisory Group for Societal Challenge 5: 'Climate Action, Environment, Resource Efficiency and Raw Materials'

3) What is the output that could be foreseen, what could the impact be, what would success look like, and what are the opportunities for international linkages?

Continental Shelf Prehistoric Research will contribute to the social awareness of such a research discipline. The discoveries will add to local museum collections, boosting coastal tourism. The sea level changes and human interactions implied from this research will contribute to the understanding of future impacts from climate change. Endangered prehistoric sites will be preserved and cultural heritage management improved.

The European research community involved in Continental Shelf Prehistoric Research, a topic supported by multinational and international organizations, is very active and increasing. However, the structure is still informal and transitory. With a new coordinated research effort at European level, the potential for new discoveries and benefits from international linkages would be vast. For example, the International Union of Quaternary Research[53] (INQUA) and the International Geoscience Programme[54] (IGCP) have, for decades, recognized and occasionally supported the human/hominin dimension in Quaternary/Pleistocene research, including the role of the continental shelf, but not including the direct study of submerged sites. Similarly, major international conference series occasionally hold a session on continental shelf submerged sites, such as the World Archaeological Congress[55] (WAC-6, Ireland, 2008). The UNESCO Office for Underwater Cultural Heritage recognizes the importance of the prehistoric continental shelf, and organized a Scientific Colloquium (Brussels, 2011)[56] on factors impacting underwater cultural heritage. Europe has been a leader in Continental Shelf Prehistoric Research, and we need to consolidate and expand that advantage to encompass an international dimension.

4) Which are the bottlenecks in addressing these areas, and what are the inherent risks and uncertainties, and how could these be addressed?

We identify the bottlenecks in three perspectives: data and technology support, cross-disciplinary awareness and management.

Support (data and technology)

- Insufficient availability of high resolution seabed mapping;
- Requirement for new software to convert bathymetry and sediment data into reconstructed palaeo-terrain and landscapes;
- Necessity for novel methodologies for remote operated site confirmation, possibly through geochemical or DNA-based techniques;
- Lack of availability of ship time.

These could be addressed following the recommendations of bullets I, II and III in Question 1.

[53] EINQUA http://www.inqua.org/

[54] Launched in 1972 and originally termed as "International Geological Correlation Programme," is a cooperative enterprise of UNESCO and the International Union of Geological Sciences (IUGS). http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/international-geoscience-programme/

[55] WAC: http://www.worldarchaeologicalcongress.org/; WAC-6: http://www.worldarchaeologicalcongress.org/site/wacpress_20.php

[56] http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/dynamic-content-single-view/news/international_scientific_colloquium_on_the_factors_impacting_underwater_cultural_heritage_at_the_royal_library_of_belgium/#.U5AzAih-hSI

Knowledge & awareness

Lack of mutual understanding between disciplines: for example, archaeologists lack of familiarity with modern acoustic technology and engineers and geologists not appreciating the needs of archaeologists.

These could be addressed following the recommendations of bullets I, II and IV in Question 1.

Management

The biggest risk is mismanagement. Poor training and lack of access to available technology and data will lead to difficulties in multidisciplinary surveys at a shared operational cost. Lack of such alliance effort will unfortunately result in prehistoric sites being destroyed by human activities (e.g. industrial operators) or natural disasters (e.g. storms).

These could be addressed following the recommendations of bullets I, III and IV in Question 1.

5) Which gaps (science and technology, market, policy) and potential game changers, including the role of the public sector in accelerating changes, need to be taken into account?

The gaps for Continental Shelf Prehistoric Research exist in knowledge (e.g. time and location of the recorded sites and trans-disciplinary awareness) and policy (e.g. a coordinated and sustainable structure through which relevant stakeholders can liaise), as noted in previous sections. However, besides recognizing the value of protecting seabed prehistoric sites, it is important for authorities to develop systematic procedures, e.g. from identification, assessment, survey and protection to excavation. A comprehensive governance mechanism plays an important role in supporting such activities that sometimes take place at national boundaries. The procedures to oversee these activities at European level are necessary to ensure compliance with existing treaties and legislations.

6) In which areas is the strongest potential to leverage the EU knowledge base for innovation and, in particular, ensure the participation of industry and SMEs? What is the best balance between bottom-up activities and support to key industrial roadmaps?

Cultural heritage assets, recognized for their contribution to sustainable growth and job creation, are subject to damage from human activities (e.g. offshore operation) and natural disasters (e.g. climate change induced storms). Europe possesses strong potential from its knowledge resources for prevention of such damage occurring, if coordinated mechanisms and knowledge alliances are established.

Direct interactions between high-profile industry representatives and researchers proved very fruitful, as demonstrated in the SPLASHCOS Esbjerg Meeting[57]. The community has recognized that for Continental Shelf Prehistoric Research, it is important to engage in dialogue with the fishing industry (by reporting by-catch) and to develop voluntary codes of practice with aggregate dredging companies. Such initiatives should be supported from regional to pan-European level.

Offshore industries usually start projects with intensive geological and geophysical surveys for information, which may also be a fundamental requirement for reconstruction of submerged landscapes in high resolution. Drilled cores from these investigations may allow additional geochemical, palynological or macrofossil analyses and dating, that produce important data about local landscape and sea level history. There are already examples of fruitful

[57]SPLASHCOS Esbjerg Meeting (14-16 March 2013) http://www.splashcos.org/events/splashcos-esbjerg-meeting

cooperation in Europe between the marine industry and research on submerged landscapes, such as the Doggerland project that integrated datasets from marine industries for modelling the prehistoric landscape[58]. Such cooperation also contributes to a better understanding by industry managers to the scientific interests of submerged landscape research.

7) Which areas have the most potential to support integrated activities, in particular across the societal challenges and applying key enabling technologies in the societal challenges and vice versa: and cross-cutting activities such as social sciences and humanities, responsible research and innovation including gender aspects, and climate and sustainable development? Which types of interdisciplinary activities will be supported?

Sea level rise is one of the most direct manifestations of a warming climate and is highlighted as one of the key research priorities by the European Marine Board[58]. Continental Shelf Prehistoric Research, a new trans-disciplinary domain that links sea level change with prehistoric human activities, has the potential to address one of the most pressing societal challenges via studying the past, and calibrating models of past climatic events. As stated previously, this research requires an integrated effort from diverse academic disciplines, cultural heritages, and industries. The trans-border nature of Continental Shelf Prehistoric Research usually falls outside the national research agenda and tends to be divided across EU research themes. It is therefore important that a solution-oriented R&I programme in the spirit of Horizon 2020 addresses this topic.

[58] Gaffney V, Fitch S and Smith D (2009) Europe's lost world: the rediscovery of Doggerland. CBA research report 1955

[59] European Marine Board (2013) Position Paper 20, Navigating the Future IV, Chapter 2; CLAMER-EMB report (2011) Systhesis of European Research on the Effects of Climate Change on Marine Environments. http://www.marineboard.eu/publications

Annex 4

Detailed list of recommendations

Detailed listing of conclusions and recommendations under the same headings as Chapter 7

PROCEDURAL AND REGULATORY, INSTITUTIONAL

1. Encourage those countries/agencies which do not identify submerged prehistoric landscapes and archaeology as a sector for cultural heritage protection to up-date their legislation and implementation.
2. Promote integrated collaboration between Cultural Heritage agencies and marine geoscience and operational marine agencies, especially through the sharing of ship time costs.
3. Identify agencies responsible for Marine Spatial Planning in all coastal states and check their policies on submerged prehistoric landscapes and prehistoric archaeology; promote integration of protection for prehistoric sites in national MSP.
4. Develop teams competent in Continental Shelf Prehistoric Research who can provide services on a contract basis anywhere in the world, producing income and business.
5. Collaboration between disciplines and agencies is essential during all stages of Continental Shelf Prehistoric Research.
6. Integration of predictive modelling into European Marine Spatial Planning
7. The existing successful but scattered community of researchers in continental shelf prehistoric research needs to develop a new strategic layer to plan co-ordinated projects, support training, and develop the case for funding at a European level.

STRATEGY

8. CSPR is a long term integrated research theme, which produces results slowly and steadily, with an acceleration of results due to the ability to interconnect data. Meanwhile the archaeological relics on the sea floor are eroding. A consistent steady approach is needed.
9. Europe is in the lead globally, and we should build on this to keep the lead. The USA is starting to invest seriously after a number of successful isolated projects.
10. Europe may take the lead of a new research, and provide skills and teams of experts to work in other areas.
11. Increasing use of continental shelves foreseen for the next decades (Blue Growth, energy...) forces us to assess the direct or indirect consequences for cultural heritage research offshore, and turn the situation to mutual advantage wherever possible.
12. The SPLASHCOS Action provides a wealth of data and experience to build upon to justify and achieve strategic planning, but this must be done rapidly to exploit the existing momentum.
13. Collaboration and sharing of resources is required across academic boundaries, both in training, use of data, and access to technology.
14. Integration of submerged prehistoric landscape research as a research objective of the European research programs.

ARCHAEOLOGICAL OBJECTIVES

15. Focus Continental Shelf Prehistoric Research funding at the supra-national level on the following archaeological themes:
    - Identify and describe cultural assemblages and life-ways of early coastal settlements in palaeoenvironments and landscapes for which there is no modern analogue;
    - Discover and map the continental shelf component of Palaeolithic pathways of migration and dispersal into Europe;
    - Research present and now submerged past archipelago areas for evidence of early short distance seafaring and channel crossings;
    - Search for evidence of the earliest wide channel crossings, offshore fishing, seal hunting, and visits to offhsore islands fo resources;
    - The emormous impact of sea level change and coastal changes on social geography, demography, economic organization, and cultural interactions of ancient populations;

- The early history of coastal sedentism, with year-round settlements, permanent dwellings, and durable structures of wood or stone;
- The significance of coastal regions in providing fertile cultivation for early farmers, pathways for expansion of farming from the Near East to southern Europe, and the origins of mixed diets;
- Develop integrated analysis of prehistoric cultures seamlessly between the present land surface and the submerged continental shelf;
- Priorities identified in the EAC survey (Annex 5 & 6).

16. Identify groups working on human genetics and migrations in the Europe-Middle East- Africa region and develop collaborative programmes to locate key continental shelf signals that would correlate with, confirm, or refute DNA-based hypotheses.
17. Promote conservation and protection of submerged archaeological sites, and the display of research and discoveries in museums and tourist resorts, in compliance with the Blue Growth Plan para.22. in order to encourage tourism.
18. Research is needed into early periglacial living styles. When did people first prefer living near the ice by choice?
19. New era opens for prehistoric archaeology, needs collaborative trans-disciplinary (not only trans-sciences but trans-cultural and scientific researches)
20. Conduct strategic analysis on major gaps in site occurrence, both in time and location, related to key archaeological questions. What kinds of sites are lacking, or are needed most critically to confirm or reject models or theories, or to fill gaps in theories?
21. Find a long-term (at least 5-years) source of funding for the SPLASHCOS Inventory of Continental Shelf Prehistoric Sites, sufficient to fund a part-time assistant to maintain the data base and solicit for up-dating of entries.
22. Offshore development initiatives should include investigations to estimate the impact of the planned activity to the submerged prehistoric landscape and occupation remains with care for salvaging and documentation of those parts that cannot be safeguarded in-situ. All relevant data from pre-disturbance surveys and during operations should be made available to cultural heritage and research agencies.

TRAINING, EDUCATION, PUBLICATIONS, WEB SERVICES

23. Establish a web-site for providing news, information on lectures and courses, links between teaching establishments, colleges, and training agencies, with course material and information on projects in the planning phase.
24. Organize international conference series on Continental Shelf prehistoric Science at intervals of 2-3 years.
25. Investigate possibility of an electronic web-journal for publication of papers on Continental Shelf Prehistoric Research and its related disciplines.
26. Encourage a small number of university archaeology departments to specialize in CSPR as a research discipline and supporting Cultural Heritage management.
27. Establishment of an endowed professorship for submerged prehistoric landscape research. Funding sources need to be investigated.
28. Contact diver training programmes that specialize in underwater archaeology, and promote CSPR as a topic in their courses.
29. Develop training courses or familiarisation courses for engineers and marine geoscientists to provide them with understanding of Continental Shelf Prehistoric Research and guidance for offshore operations
30. Promote practical training courses and transfer of technology courses similar to those that were successful in SPLASHCOS.
31. Develop CSPR course material both for research careers, and for employment by commercial contract archaeology companies and non-profit organizations.
32. Establish academic course materials and life-long training to prepare specialists in this field.
33. Public awareness - link protection of submerged heritage to public response and appreciation of climate change effects – as people become more aware of it new sites are bound to be documented (schools, media, documentaries, museums)
34. Education in special courses or university degrees (master, phD), open for bachelors from archeology, geology and technical engineers.

FUNDING SOURCES

35. Promote the uptake of Continental Shelf Prehistoric Research as a priority for funding in the research agenda of the relevant JPI's (Ocean, and Cultural Heritage). Check which countries would support it. Funding through JPI's seems a logical opportunity for a subject which spans several disciplines and agencies
36. At present the categorisation of calls and project proposals into different disciplines or targets militates against a field of research that includes both humanities and geosciences. EMB and EAC may be able to collaborate on guidelines or recommendations that would help to resolve this problem. The concept of ecosystem management could be extended to include cultural issues.

GEOSCIENCE OBJECTIVES

37. Reconstruct the climate and vegetation of the continental shelf at 1000 year intervals for the whole European shelf from 20,000 to 5000 years BP.
38. Emphasize research on very high resolution ice edge models of Pleistocene ice caps through time, so as to define periglacial environmental conditions, and tundra extent., and marine or terrestrial fauna at the ice edge, including glacial lakes.
39. Improve modelling of GIA sea level models, additional to local and regional tectonics, and computing accurate palaeo-coastlines, at intervals of 1000 years since the LGM.
40. Reconstruct multi-period mapping of palaeo-river valleys on the shelf, noting probability of meandering valleys on low gradients, and incised valleys with infill.
41. Conduct marine geomorphological research on coastal and seabed environments to a depth of 50m in those areas which have not so far revealed submerged prehistoric sites so as to analyse the probable processes which would influence both site occurrence and site modification during inundation. The Croation coast is an example of success of this kind.
42. Use prehistoric remains as indicators of relative sea level so as to improve sea level models and identification of palaeo-coastlines.
43. Consider using archaeological sites as sea-level index-points.

INDUSTRIAL COLLABORATION, STAKEHOLDERS, PARTNERS

44. Collaborate with industries (offshore hydrocarbons, windfarms, dredging, fisheries, civil engineering) to develop codes of practice, thus minimising costs and improving conservation of sites, and assisting research.
45. Collaborate with industry, dredgers, fishermen, and divers to encourage reporting of finds, and distribute recognition charts and identikit posters for CSPR indictaors.
46. Collaborate with industry and government geological agencies to extract relict terrestrial features recognition from bathymetric and geological data. (Note that gridded data frequently conceals or eliminates very significant discontinuities and abrupt changes of gradient).
47. Develop literature, information, and web-contacts with stakeholders such as sports divers, fossil collectors, fossil shops, amateur collectors and archaeologists, fishermen, and others who are likely to find palaeontological remains or prehistoric artefacts on the seabed.

TECHNOLOGY

48. There is a large potential if the whole community has access to the technology and related infrastructure (which is not the case now), but at the same time new developments are also needed.
49. Access to and sharing of infrastructure should be facilitated in EU.
50. Access to ships and ship-time (e.g. for large-scale palaeolandscape mapping) should be facilitated (Eurofleet)
51. Promote the development of improved technology.
52. Underwater imaging and monitoring technology permit new researches and CSPR may be the ground-truth field and boost further advances.

53. Cooperation between industries and science in development of excavation, sampling and documentation techniques.
54. Set up of a 'best practice' methodology/approach (from general surveys to localisation of small targets, with emphasis on the environment in different sea areas, also regarding grab samples) – part of Env. Impact Assessment (before the research is carried out)
55. Acoustic sub-bottom detection of small objects...
56. Data processing improvements are needed for merging seabed data from many sources to recreate palaeo-terrestrial landscapes and palaeo-environments.
57. Modelling software needs improvement to facilitate predictions of site occurrence and site survival or destruction.
58. ROV/AUV instrumentation can be developed specifically for prehistoric site identification and mapping.
59. Core log interpolation is needed to identify palaeo terrestrial surfaces.
60. Excavation technology needs improvement for investigating stratigraphy within submerged prehistoric sites.

DATA ACCESS, ARCHIVING AND PROCESSING

61. Work with EMODNET DG MARE to improve European-scale mapping of bathymetry, sediment thickness, and Quaternary sedimentary geology at high resolution, and improve access to data.
62. Discuss with EMODNET possibility for a Lot devoted to marine archaeology data.
63. Improve free Data-access between industries and research.

Annex 5

Questionnaire to European cultural heritage agencies

Preamble

Please find below a Questionnaire which has been prepared jointly by the Submerged Landscapes Working Group (SUBLAND) of the European Marine Board, and members of the Marine Archaeology Committee of the EAC, Chaired by Mr Fionnbarr Moore.

During recent decades over 2000 submerged prehistoric sites have been found and recorded on the floor of seas around Europe, ranging in age from 5000 years BP to over 300,000 years BP. Terms of Reference of SUBLAND and references demonstrating the widespread survival of prehistoric sites on the continental shelf, including a map of sites catalogued during the recent SPLASHCOS COST Action TD-0902, are attached as annexes.

The EAC was consulted during the nomination of members for the SUBLAND WG, and will be consulted fully in the drafting of the Position Paper to be published at the end of 2014.

Marine Archaeology includes both the study of shipwrecks and seafaring in the historic period, and submerged towns and ports of the historic period, as well as prehistoric settlements and artefacts that have been submerged by the post-glacial rise of global sea level. The latter topic, defined as Continental Shelf Prehistoric Research, has received less attention than shipwreck archaeology both by administrators, research organizations, and the general public. The definitions of archaeological obligations of states by the UN Convention on the Law of the Sea, and the UNESCO Convention on Underwater Cultural Heritage do include responsibility for prehistoric remains on the continental shelf, and recent research demonstrates how rewarding and important this new knowledge can be. Additionally it reveals how stratified anthropogenic material, including organics, can survive for tens of thousands of years under the sea. This creates a responsibility to assess the extent of the submerged prehistoric resource, to evaluate the fragility or robustness of particular sites and deposits, and the potential for conservation or protection of sites. Excavation on the seabed may sometimes be the recommended action.

The Position Paper in preparation by SUBLAND must be based on the best available information about the activities and policies of national departments and agencies regarding the submerged prehistoric sites on the continental shelf within their jurisdiction. The combined skills of archaeologists, marine research agencies, marine technologists, and geological agencies, will then ensure the best future policies and research strategies. For this reason, the SUBLAND WG is circulating the Questionnaire attached below, and requests that the completed form should be returned either electronically, or by post to:

Dr Nan-Chin Chu (nchu@esf.org), with copies to Mr Fionnbarr Moore (Fionnbarr.Moore@ahg.gov.ie) and Dr. N. C. Flemming (nflemming@sheetsheath.co.uk).

If you have queries concerning this Questionnaire, please contact any of the above.

Questionnaire to European cultural heritage agencies

BASIC INFORMATION (COMPULSORY)

1. Responding organization and person completing the questionnaire

   Name of organization ______________________________

   Address of organization ______________________________

   Name of person completing the Questionnaire ______________________________

   Post or job title of person completing the Questionnaire ______________________________

JURISDICTION AND AUTHORITY

2. Is your agency, government department, or heritage service responsible for the protection of the underwater cultural heritage or research aspects of marine archaeology, seabed archaeology, underwater archaeology, and prehistoric continental shelf archaeology in any of the seas within the jurisdiction of your country?

   ❍ Yes ❍ No

If not, to which agency, government department, should these questions be addressed?

3. Has your country become party to the following international agreements relating to cultural heritage and archaeology at sea? (Click to answer YES)

   ❍ United Nations Convention on the Law of the Sea

   ❍ UNESCO Convention on Underwater Cultural Heritage

   ❍ Valetta Convention 1992

   ❍ Other (Please Specify)

4. Does your agency, government department, heritage service, have responsibility for seabed/continental shelf prehistoric remains in the following legally defined sea areas: (Click to answer YES)

   ❍ On the beach and in the intertidal zone

   ❍ Within territorial waters

   ❍ Within the extended contiguous zone

   ❍ Within the national EEZ

   ❍ Within the legally defined continental shelf

5. Are there offshore areas of your national continental shelf for which the responsibility for prehistoric archaeological remains on the sea floor is not yet defined or not allocated to a particular agency, government department?

   ❍ Yes ❍ No

6. Add notes if required ______________________________

ASPECT OF UNDERWATER CULTURAL HERITAGE DEFINITION

7. Does your agency, government department, heritage service, have responsibility for the cultural heritage aspects of shipwrecks older than 100 years?

   ❍ Yes ❍ No

8. Does your agency, government department, heritage service have responsibility for cultural heritage aspects of prehistoric remains found on the seabed in the areas defined in question 4?

   ❍ Yes ❍ No

9. Has your country passed national legislation or ratification and enabling legislation that defines responsibility for prehistoric remains on the continental shelf?
   - ❍ Regarding protection and conservation
   - ❍ For research and interpretation
   - ❍ Legal requirements for seabed industrial or commercial operations applying for concessions

If possible, attach references to National Legislation or Departmental/Agency policy documents.

LICENSING COMMERCIAL ACTIVITIES ON THE SEABED

10. When commercial organizations or operational government agencies are planning to conduct operations on the seabed within the national jurisdiction of your country: (Select to answer YES)
    - ❍ Do they have to file plans for conducting archaeological surveys of the seabed?
    - ❍ Do these requirements include the obligation to assess the probability of disturbing prehistoric remains on the seabed?
11. If the answers to question 10 are positive, does the obligation to assess the potential occurrence of prehistoric sites include the requirement to conduct the following types of survey: (Select to answer YES)
    - ❍ Geophysical Survey
    - ❍ High Resolution Bathymetric Survey
    - ❍ ssessment by diving, ROV or other means of anomalies identified
12. If there is a probability that prehistoric remains occur on the seabed in the area which is going to be disturbed by the operations, is your agency, government department, heritage service, entitled to place a qualified archaeologist on the vessel conducting the work?

    ❍ Yes ❍ No

    Others, please specify ____
13. Is the operator required to carry on board a commercial archaeologist experienced in marine archaeology?

    ❍ Yes ❍ No

    Others, please specify ____
14. Is the operator required to monitor activities and report archaeological and prehistoric findings to you?

    ❍ Yes ❍ No
15. Are commercial data sets obtained from the seabed required to be deposited with a government agency, department, and heritage service, for archive and research purposes? and are these data available to researchers under conditions of confidentiality or open access?

    ❍ Yes ❍ No

    Others, please specify ____

TRAINING, EDUCATION AND RESEARCH

16. Are there university archaeology courses in your country which include aspects of marine archaeology and, so far as you know, do these courses also include instruction in the Pleistocene changes of sea level, and prehistoric archaeology of the continental shelf?

    ❍ Yes ❍ No

Note: UNESCO Office for the Underwater Cultural Heritage, in Paris, has a website (click here for an external document) listing marine archaeology educational and training courses by country. Please check if any of those courses include submerged prehistoric site archaeology.

17. In your country, are there research agencies, archaeological departments, heritage services or other government centres that conduct seabed archaeological research which includes prehistoric archaeology?

❍ Yes ❍ No

If yes, please name the principle institutions ______________________________

____

18. Please indicate the main research objectives which apply to the submerged prehistoric continental shelf of your country. For example:

- ❍ Migration routes to and from the coast of your country
- ❍ Population centres as a refugium from nearby lands abandoned during glacial periods
- ❍ Origins of prehistoric seafaring
- ❍ Origins of exploitation of marine resources and marine diet
- ❍ Changes in subsistence, such as the introduction of agriculture
- ❍ Study of population that has contributed to DNA of your region
- ❍ Palaeolithic re-population of recently deglaciated coastal zones
- ❍ Prehistoric non-lithic material culture which only survives in permanently waterlogged sediments
- ❍ Earliest prehistoric occupation of islands presently separated from the mainland of Europe
- ❍ Food, diet, population demographics, diseases, and life expectancy of Palaeolithic or Mesolithic populations
- ❍ Palaeo-environments and climate on the continental shelf at the Last Glacial Maximum
- ❍ Demography and human response to climate change
- ❍ Human response to rising/falling sea level during climate change
- ❍ Domestication of animals and early farming and crops
- ❍ Early hominin migrations and areas of occupation during previous glacial cycles
- ❍ Hominin and human migration or diffusion pathways from Africa into Europe
- ❍ Reconstruction of vegetation and fauna of the continental shelf, providing an environment for hominins
- ❍ Reconstruction of river channels and fresh-water drainage or karst on the submerged continental shelf
- ❍ Other

INSPECTION AND ENFORCEMENT

If the answer to Question 10 is positive, indicating that offshore operators have an obligation to conduct surveys and protect prehistoric sites on the sea floor, does you agency, government department, heritage service, have the authority to inspect and monitor offshore work for its impact on submerged prehistoric sites?

❍ Yes ❍ No

If your agency, government department or heritage service does not have this authority, is there another agency that conducts this supervision?

❍ Yes ❍ No

If yes, please give name of agency ______________________________

19. Are there legal penalties for wilful and negligent damage or looting to submerged prehistoric sites on the continental shelf or territorial waters of your country?

❍ Yes ❍ No

PUBLICATION, LEGISLATION, CODES OF PRACTICE, GUIDES AND MANUALS

Please provide examples of research plans, strategic research documents, legislation, directives, codes of practice, or guides and manuals provided to industrial operators defining the management and protection of submerged prehistoric sites.

COLLABORATION WITH MARINE GEOSCIENCE AND SURVEY AGENCIES AND INSTITUTES

It is an objective of SUBLAND to promote the collaboration between marine archaeological/cultural heritage organizations and the range of agencies, departments, and universities conducting research into topics such as marine geology, change of sea level, climate change, seabed sediments, coastal erosion, and safe navigation channels. The following table lists the kinds of agencies that are most relevant, and we ask if you know of collaboration already in your country, and whether you wish for future collaboration.

20. Marine Geoscience body with whom prehistoric seabed archaeologists could collaborate.
    Please answer Yes, No, or Don't Know.

Marine Geoscience body with whom prehistoric seabed archaeologists could collaborate	Are you aware of previous collaboration between prehistoric seabed archaeologists and these agencies in your country?	Would you favour such collaboration in future in your country?
Geological Survey Marine division		
Hydrographic Survey Office		
National Oceanographic or Marine research Agency		
Coastal Protection Erosion Agency		
Ports Authority or agency responsible for channel dredging		
Climate Change research institution or university department		
Marine Spatial Planning Office		

21. Others of the above Marine Geoscience bodies, if so please specify in the following box:

EXTENT OF DETAILED DATA PUBLISHED FROM THIS QUESTIONNAIRE

The SUBLAND WG of the European Marine Board may wish to publish analysis of the detailed replies and raw data from this questionnaire, but we appreciate that some EAC Members may not wish their replies to be made public. On the other hand, the raw data of the replies might be of significant policy value to all EAC Agencies. We value your advice on the best way to use the data from this survey: (Select to answer YES)

Your preferred use of the data would be:

- ❍ Full publication of the analysis of the survey response in the SUBLAND Position Paper, with the tabulated response data attached as an annexe or available electronically on request to all readers of the Paper
- ❍ Full publication of the analysis of the survey response in the SUBLAND Position Paper, with the tabulated response data provided confidentially only to members of EAC and the European Marine Board
- ❍ Abbreviated summary of the statistics of the survey response in the text of SUBLAND Position Paper, with a fuller discussion in an annexe, and the full tabulated response data provided confidentially only to members of EAC and the European Marine Board

We thank you very much for your time and expertise in completing this Questionnaire. We will keep you informed of the progress with responses, and will circulate the tabulated data for comment before any decision is taken about the extent of detailed publication.

Sincerely,
Fionnbarr Moore, Nicholas Flemming, Birgitte Skar, and Nan-Chin-Chu

Annex 6

Questionnaire analyses

Introduction

The Submerged Landscapes Working Group (SUBLAND) of the European Marine Board, and members of the Marine Archaeology Committee of the EAC, Chaired by Mr Fionnbarr Moore have carried out a survey among Member Government Departments and Agencies of the European Archaeology Council plus Norway. The SUBLAND WG has circulated a Questionnaire shown in Annex 5.

The summary below is based on the 15 responses as received by 20th May 2014.

The intent of the survey is to support the Position Paper in preparation by SUBLAND so that it is based on the best available information about the activities and policies of national departments and agencies regarding the submerged prehistoric sites on the continental shelf within their jurisdiction. The combined skills of archaeologists, marine research agencies, marine technologists, and geological agencies, will then ensure the best future policies and research strategies.

The questionnaire and responses

Questionnaires were distributed to all EAC Member Organizations, in 28 nations, and 15 agencies and departments replied representing varied jurisdictions in 12 nations. The comprehensive questionnaire comprises 8 different issues of interest. This report is structured according to these issues. Most of the respondents have answered all questions, but some have left some answers out, presumably because the answer to the question was unknown.

The responses

BACKGROUND INFORMATION

The 15 respondents represent a mixture of management levels, national and regional, from 12 different countries: Northern Ireland, Scotland, England, Iceland, Norway, Denmark, Germany, Belgium, The Netherlands, Slovenia, Portugal and Greece. This provides information on management in part of The Atlantic, The Irish Sea, the North Sea, The Channel, The Western Baltic, a small part of the Adriatic and The Ionian, The Aegean and the Eastern Mediterranean. The survey also mirrors differences in heritage management organization among the nations. The response represents almost all the members of the EAC Underwater Cultural Heritage WG, plus several agencies that are not members of that WG, and represents an acceptable response from the 28 countries which are affiliated to the EAC, four of which are landlocked with no sea coast. Half of the countries with sea coasts are represented, some with more than one agency. The summary of responses below is by agency, so that the number of responses quoted may sometimes exceed the number of countries.

JURISDICTION AND AUTHORITY

Question 2

Is your agency, government department, or heritage service responsible for the protection of the underwater cultural heritage or research aspects of marine archaeology, seabed archaeology, underwater archaeology, and prehistoric continental shelf archaeology in any of the seas within the jurisdiction of your country?

While 12 of the respondents confirm this issue one respondent (Belgium) comments that heritage responsibility in territorial waters and on the continental shelf is the responsibility of the federal state in Belgium, while heritage management in the intertidal zone is the responsibility of the regional management authority. Another – English heritage – responds that the responsibility for management policies in the coastal areas of England is the Department of Culture, Media and Sports.

Question 3

Has your country become party to the following international agreements relating to cultural heritage and archaeology at sea?

Both the United Nations Convention on the Law of the Sea and Valetta Convention 1992 are signed by most of the respondents (13), while it is notable that less than half of the countries/respondents have signed on to the UNESCO convention on underwater cultural heritage (5). England and the Netherland remark that they have signed the European Landscape Convention. This particular convention is actually signed by more of the responding countries, but likely not associated with management of the seabed.

Question 4

Does your agency, government department, heritage service, have responsibility for seabed/continental shelf prehistoric remains in the following legally defined sea areas?

We can conclude that most of our respondents carry responsibility within the beach and intertidal zone (11). 4 respondents: Germany; Scotland, Norway and Iceland have, however, responded that they are not responsible for management on the beach and in the intertidal zone. For Norway there seems to be a difference in responsibility for Maritime Museums between regions of Norway. Most of our respondents are also responsible for management within the territorial waters (sea) (12).

Only a few of our respondents are responsible for archaeology within the extended contiguous zone (4), Norway, The Netherlands, Greece and Denmark.

Most of the respondents are not responsible for heritage management within the economic zone (EEZ), except for the Netherlands (1). This respondent comments that EEZ and the continental shelf are the same area for the Netherlands. Responsibility for heritage is limited to the effects on heritage during economic activities (dredging, oil/gas exploration).

Most of the respondents are not responsible for heritage management within the legally defined continental shelf (2) except for Historic Scotland that remarks that Scottish Ministers have planning and marine licensing powers within the UK marine area adjacent to Scotland (0-200nms) and this could encompass some consideration for prehistoric archaeological remains. Powers to designate as a scheduled monument of Historic Marine Protected Area a nationally significant discovery could only be made within territorial waters (0-12 miles).

Question 5

Are there offshore areas of your national continental shelf for which the responsibility for prehistoric archaeological remains on the sea floor is not yet defined or not allocated to a particular agency, government department?

The German, one of the Norwegian and the Portuguese respondents (3) answers yes to this question, while all other respondents (11) respond that there are no such undefined areas.

Question 6

Additional Notes

Three respondents have commented on the question. England comments that the overall responsibility for heritage in UK marine area waters adjacent to English Territorial Waters is governed by the Department of Culture, Media and Sport. Scotland comments that Scottish ministers have planning and marine licensing powers within the UK marine area adjacent to Scotland. And the Netherlands comment that EEZ and the continental shelf are the same for The Netherlands, responsibility for heritage is limited to the effects on heritage during economic activities (dredging, oil/gas).

Summarizing this section it can be said that the areas closest to the shore i.e. the beach and intertidal zone as well as territorial waters are generally managed by national/regional heritage authorities. Regarding the contiguous zone, the economic zone and the shelf there is a variety among nations - it is only the Netherlands and Scotland that claim authority in the EEZ and the legally defined continental shelf.

ASPECT OF UNDERWATER CULTURAL HERITAGE DEFINITION

Question 7

Does your agency, government department, heritage service, have responsibility for the cultural heritage aspects of shipwrecks older than 100 years?

12 respondents answer affirmative to this question, the respondent from Belgium comments that this pertains to wrecks that are situated within the intertidal zone.

Question 8

Does your agency, government department, heritage service have responsibility for cultural heritage aspects of prehistoric remains found on the seabed in the areas defined in question 4?

13 respondents confirm that they carry responsibility for prehistoric remains found on the seabed defined in question 4. The Belgian respondent comments that this applies to the intertidal zone, the beach and inland waters.

Question 9

Has your country passed national legislation or ratification and enabling legislation that defines responsibility for prehistoric remains on the continental shelf?

❍ **Regarding protection and conservation** (6)

The German, Danish, Belgian, Slovenian, English and Greek respondents confirm that such legislation or ratification has been established. The Belgian respondent comments that federal law mainly dealing with protection and conservation is expected to enter into force within months.

❍ **For research and interpretation** (3)

German, Slovenian and Greek respondents confirm that legislation and ratification enables research and interpretation.

❍ **Legal requirements for seabed industrial or commercial operations applying for concessions** (8)
Slovenia, Scotland, England, Ireland, Norway, The Netherlands, Greece and Denmark confirm that there are legal requirements for industrial and commercial operations applying for concessions.

Some of the respondents give important comments and references[60]

Summarizing the above it can be said that prehistoric remains found on the seabed are to a large degree covered or intended to be covered by legal measures among the responding nations. The most common rule is that legal requirements for seabed industrial and commercial operations apply. Legislation for protection and conservations is also widespread. Research and interpretation is rather weakly covered by laws. A number of interesting references are given (see footnote).

LICENSING COMMERCIAL ACTIVITIES ON THE SEABED

Question 10

When commercial organizations or operational government agencies are planning to conduct operations on the seabed within the national jurisdiction of your country:

❍ **Do they have to file plans for conducting archaeological surveys of the seabed?** (8)
Slovenia, Scotland, Northern Ireland, Norway, The Netherlands and Greece confirm that such plans have to be filed.

❍ **Do these requirements include the obligation to assess the probability of disturbing prehistoric remains on the seabed?** (10)

The same respondents plus England and Denmark confirm that the probability of disturbing prehistoric remains on the seabed have to be assessed.

Summarizing this section: both filing plans and assessing the probability of disturbing prehistoric remains on the seabed are requirements seem to be widespread among the respondents.

[60]Belgian respondent: Federal law mainly dealing with protection and conservation is expected to enter into force within months. Slovenian respondent: Cultural Heritage Protection Act (Official gazette of Republic of Slovenia, nos. 16/08, with amendments) 2. Rules on Archaeological Research (Official gazette of Republic of Slovenia, Slovenianno. 3/13) 3. Environmental Protection Act (Official gazette of Republic of Slovenia, no. 41/04, with amendments) 4. Act regarding the siting of spatial arrangements of national Slovenianno. 3/13) 3. Environmental Protection Act (Official gazette of Republic of Slovenia, no. 41/04, with amendments) 4. Act regarding the siting of spatial arrangements of national significance in physical space (Official gazette of Republic of Slovenia, no. 88/10, with amendments) 5. Spatial Management Act (Official gazette of Republic of Slovenia, no. 110/02. Historic Scotland: Planning and licensing powers in the UK Marine and Coastal Access Act 2009 refer to consideration of sites of historical or archaeological interest and this could encompass prehistoric archaeology on the continental shelf. Relevant policies are Scottish Historic Environment Policy; UK Marine Policy Statement; Relevant legislation for protection (territorial waters only) is Marine (Scotland) Act 2010 and Ancient Monuments and Archaeological Areas Act 1979 as amended in Scotland by the Historic Environment (Amendment). Historic Scotland) Act 2011. English Heritage: Within Territorial Waters off England: Ancient Monuments and Archaeological Areas Act 1979; for planning and licensing: Marine and Coastal Access Act 2009. Irish respondent:Marine and Coastal Access (MCAA) Act 2009 has implications for marine archaeology, including prehistoric remains, through the licensing of marine activities and controls over offshore development. The Netherlands: Ontgrondingenwet, Wet Milieubeheer, Mijnbouwwet, Nationaal Waterplan, Integraal beheersplan Noordzee, Visie Erfgoed en Ruimte, Structuurvisie Infrastructuur. Denmark: The Museum Act.

Question 11

If the answers to question 10 are positive, does the obligation to assess the potential occurrence of prehistoric sites include the requirement to conduct the following types of survey?

❍ **Geophysical Survey** (7)
Scotland; England, Northern Ireland, Norway, the Netherlands, Greece and Denmark reply positively to this question

❍ **High Resolution Bathymetric Survey** (8)
The same institutions plus Slovenia reply affirmative.

❍ **Assessment by diving, ROV or other means of anomalies identified** (7)
The above institutions minus England reply affirmative

Question 12

If there is a probability that prehistoric remains occur on the seabed in the area which is going to be disturbed by the operations, is your agency, government department, heritage service, entitled to place a qualified archaeologist on the vessel conducting the work?

Yes (6) Slovenia, Northern Ireland, Norway, The Netherlands and Greece
No (8) Germany, Belgium, Scotland, Portugal, English heritage, Norway and Denmark
While Norwegian agencies answer both yes and no to this question, Scotland comments: The requirement for archaeological assessment could be imposed through the EIA process or as a condition on a marine license. Such conditions would be unlikely to be imposed for every development- i.e. only where there was a likelihood that prehistoric remains might occur and be impacted significantly by development. England comments: On a case by case basis according to the significance of the possible remains, conditions can be proposed on Marine Licenses. Denmark comments: Pre-investigations are conducted by a licensed museum.

Question 13

Is the operator required to carry on board a commercial archaeologist experienced in marine archaeology?

Yes (4)
Historic Scotland, English Heritage, Northern Ireland and the Netherlands confirm this question
- Greece comments: The operator is required to carry on board an underwater archaeologist
- The Netherlands comment: this can be a requirement, but will not often be required
- English Heritage comments: If specified by Marine License condition

No (8)
Germany, Belgium, Slovenia, Portugal, NMM (NO), NTNU VM (NO)
Denmark comments: This is handled beforehand by a dedicated archaeological pre-investigation.

Question 14

Is the operator required to monitor activities and report archaeological and prehistoric findings to you?

Yes (10)
Belgium, Slovenia, Scotland, England, Northern Ireland, Norway, the Netherlands, Greece and Denmark
Belgium comments: Reporting should not be done towards the respondent but to an official who is qualified to receive underwater heritage.
No (3)
Portugal and Germany

Question 15

Are commercial data sets obtained from the seabed required to be deposited with a government agency, department, and heritage service, for archive and research purposes? And are these data available to researchers under conditions of confidentiality or open access?

Yes (6)
Slovenia, Scotland, Portugal, England, The Netherlands.
Portugal comments: In theory.
No (6)
Germany, Belgium, Northern Ireland, Norway.

- Greece comments: These data are available to researchers, only after special permission from the Ministry of Culture and Sports.
- The Netherlands comment: There is a legal obligation to make this data available for archaeological heritage management purposes. Until now this has not happened.
- Northern Ireland comments: Sometimes happens but no formal mechanism in place.
- England comments: Requirement of Marine License to archive reports and data with the English Heritage Archive.
- Scotland comments: The requirement to archive copies of archaeological reports and relevant data with the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) and the adjacent Local Authority Archaeology Service would usually be fulfilled as a condition of a marine license on open access arrangements upon granting of that license.
- Belgium comments: There are intentions to do so.

Summarizing this section: The countries around the Irish Sea, North Sea and the Western Baltic as well as the Eastern Mediterranean answer positive to most of the questions that indicate a systematic regulation and include measures with respect to heritage and prehistoric sites. Denmark seems to take complete control by involving their own pre-investigations when operations and intervention are planned on the seabed, while the other nations to some degree collaborate with the developer in order to have qualified personnel on board and monitor the seabed. Scotland and England impose demands on a case-by-case basis or through EIA processes. When it comes to obtaining commercial datasets from developers it seems to be the countries that apply a licensing instrument that have the strongest regulations for obtaining and archiving such data. Greece is strongly regulating access to such data towards research while in several countries there is an intention to do so, but it does not happen.

TRAINING, EDUCATION AND RESEARCH

Question 16

Are there university archaeology courses in your country which include aspects of marine archaeology and, so far as you know, do these courses also include instruction in the Pleistocene changes of sea level, and prehistoric archaeology of the continental shelf?

Yes (7) Belgium, Slovenia, Scotland, England, Norway, The Netherlands, Denmark
No (3) Northern Ireland, Norway and Greece

Question 17

In your country, are there research agencies, archaeological departments, heritage services or other government centers that conduct seabed archaeological research which includes prehistoric archaeology?

Yes (10) Germany, Belgium, Slovenia, Scotland, England, Northern Ireland, NMM(NO), The Netherlands, Greece and Denmark.
No (1) Germany (a regional response).

Question 18

Please indicate the main research objectives which apply to the submerged prehistoric continental shelf of your country.

For example: (A) Migration routes to and from the coast of your country (B) Population centres as a refugium from nearby lands abandoned during glacial periods (C) Origins of prehistoric seafaring (D) Origins of exploitation of marine resources and marine diet (E) Changes in subsistence, such as the introduction of agriculture (F) Study of population that has contributed to DNA of your region (G) Palaeolithic re-population of recently deglaciated coastal zones (H) Prehistoric non-lithic material culture which only survives in permanently waterlogged sediments (I) Earliest prehistoric occupation of islands presently separated from the mainland of Europe (J) Food, diet, population demographics, diseases, and life expectancy of Palaeolithic or Mesolithic populations (K) Palaeo-environments and climate on the continental shelf at the Last Glacial Maximum (L) Demography and human response to climate change (M) Human response to rising/falling sea level during climate change (N) Domestication of animals and early farming and crops (O) Early hominin migrations and areas of occupation during previous glacial cycles (P) Hominin and human migration or diffusion pathways from Africa into Europe (Q) Reconstruction of vegetation and fauna of the continental shelf, providing an environment for hominins (R) Reconstruction of river channels and fresh-water drainage or karst on the submerged continental shelf

(D) Origins of exploitation of marine resources and marine diet (10)
(M) Human response to rising/falling sea level during climate change (10)
(R) Reconstruction of river channels and fresh-water drainage or karst on the submerged continental shelf (9)
(L) Demography and human response to climate change (8)
(A) Migration routes to and from the coast of your country (7)
(I) Earliest prehistoric occupation of islands presently separated from the mainland of Europe (7)
(K) Palaeo-environments and climate on the continental shelf at the Last Glacial Maximum (7)
(C) Origins of prehistoric seafaring (6)
(H) Prehistoric non-lithic material culture which only survives in permanently waterlogged sediments (6)
(Q) Reconstruction of vegetation and fauna of the continental shelf, providing an environment for hominins (6)
(G) Palaeolithic re-population of recently deglaciated coastal zones (5)
(E) Changes in subsistence, such as the introduction of agriculture (4)
(F) Study of population that has contributed to DNA of your region (4)
(J) Food, diet, population demographics, diseases, and life expectancy of Palaeolithic or Mesolithic populations (4)
(B) Population centres as a refugium from nearby lands abandoned during glacial periods (3)
(O) Early hominin migrations and areas of occupation during previous glacial cycles (3)
(N) Domestication of animals and early farming and crops (1)
(P) Hominin and human migration or diffusion pathways from Africa into Europe (0)
Other (0)

Summarizing this section: In several of the responding countries there is a university education course specialising in marine archaeology and that includes some teaching in Pleistocene conditions and the potential of prehistoric archaeology on the continental shelf. Most of the responding countries have heritage services that include responsibility for seabed archaeological survey and prehistoric archaeology. The answers to question 18 on main research objectives which apply to the submerged prehistoric continental shelf show the priorities of the Cultural Heritage Agencies. Interestingly, all topics get some votes, except Hominin and human migration or diffusion pathways from Africa into Europe, which is obviously a big topic for some research groups, but not a national cultural agency concern in most countries. The role of seabed settlement on domestication of animals and early farming and crops are issues that are highly dependent on regional geological condition during the relevant time, which can be why this issue is prioritized by only one respondent. The answers otherwise correspond broadly to the focus and the activities that have had the most prominent attention in recent international projects and thus mirror a rising and promising awareness of the submerged archaeological record among heritage practitioners.

INSPECTION AND ENFORCEMENT

Question 19

If the answer to Question 10 is positive, indicating that offshore operators have an obligation to conduct surveys and protect prehistoric sites on the sea floor, does your agency, government department, heritage service, have the authority to inspect and monitor offshore work for its impact on submerged prehistoric sites?

Yes (6) Slovenia, Scotland, Northern Ireland, Norway, Greece.
No (3) England, the Netherlands, Germany.

Question 20

If your agency, government department or heritage service does not have this authority, is there another agency that conducts this supervision?

Yes (2) England, The Netherlands
- English Heritage comments: Marine Management Organization
- The Netherlands comments: The heritage Inspectorate.

No (1) Greece

Question 21

Are there legal penalties for wilful and negligent damage or looting to submerged prehistoric sites on the continental shelf or territorial waters of your country?

Yes (9) Belgium, Slovenia, Scotland, England, Northern Ireland, Norway, The Netherlands and Greece
- Belgium comments: in the new law of UCH
- The Netherlands comments – yes to territorial waters

No (2) The Netherlands, Germany
The Netherlands comment: no to continental shelf.

Summarizing section: Considering inspection and enforcement there are in the majority of the responding countries legal measures associated with development and obligations to protect submerged prehistoric sites on the managed territorial waters.

PUBLICATION, LEGISLATION, CODE OF PRACTICE, GUIDES AND MANUALS

Question 22

Please provide examples of research plans, strategic research documents, legislation, directives, codes of practice, or guides and manuals provided to industrial operators defining the management and protection of submerged prehistoric sites.

See footnote[61].

COLLABORATION WITH MARINE GEOSCIENCE AND SURVEY AGENCIES AND INSTITUTES

Question 23-1

Geological Survey Marine division
Are you aware of: (9) yes, (1) don't know, (1) no
Would you favour: (9) yes, (1) no

Question 23-2

Hydrographic Survey Office
Are you aware of: (6) yes, (2) don't know, (2) no
Would you favour: (9) yes

Question 23-3

National Oceanographic or Marine research Agency
Are you aware of: (6) yes, (2) don't know, (2) no
Would you favour: (9) yes , (1) don't know

Question 23-4

Coastal Protection Erosion Agency
Are you aware of: (5) yes, (1) don't know, (1) no
Would you favour: (4) yes, (1) don't know

Question 23-5

Ports Authority or agency responsible for channel dredging
Are you aware of: (6) yes, (1) don't know, (3) no
Would you favour: (8) yes

Question 23-6

Climate Change research institution or university department
Are you aware of: (4) yes , (1) don't know, (3) no
Would you favour: (7) yes, (1) don't know

[61] Belgium: Such documents are in preparation by the aforementioned project on archaeological heritage in the North Sea. Scotland: No specific documents relating to submerged prehistoric sites but this topic is covered in a variety of different guidance documents. England: JNAPC Code of Practice for Seabed Development 2006, BMAPA Marine Aggregate Industry Protocol for the Reporting of Finds of Archaeological Interest 2005, COWRIE Offshore Historic Environment Guidance for the Offshore Renewable Sector, Crown Estate 2010 Model Clauses for Archaeological Written Scheme of Investigation, Crown Estate 2010 Protocol for Archaeological Discoveries. Northern Ireland: No specific NI guidance notes. Norway: Gundersen, Kvalø and Nævestad, 2008; Kulturminner og petroleumsutvinning i Nordsjøen. Håndtering av kulturminnehensyn på sjøbunnen. National Maritime Museum; 51. Oslo. The Netherlands: NSPRMF, Wetenschappelijk Maasvlakte 2, Convenant RWS, NoAA, Herkennen van vondsten tijdens uitvoering, vondstprotocollen MV2, Ontgrondingenwet, Mijnbouwbesluit, NoAA

Question 23-7

Marine Spatial Planning Office
Are you aware of: (7) yes, (2) don't know, (2) no
Would you favour: (8) yes, (1) no

Summarizing: The section on collaboration with marine geoscience and survey agencies and institutes, does not report which types of geoscientific collaboration actually take place in the responding countries – but it gives a clear indication that the respondents see potential in such collaboration across all the mentioned sectors.

Question 24

Others of the above Marine Geoscience bodies, if so please specify in the following box:

- Scotland comments: Natural heritage agencies (Scottish Natural Heritage)
- Northern Ireland comments: E.g., Marine Division (DOE NI)
- The Netherlands comments: Deltares, Utrecht University, faculty of Geo Sciences, Groningen University, faculty of Archaeology, Leiden University, faculty of Archaeology
- Greece comments: Hellenic Centre for Marine Research

Question 25

Use of data

Full publication of the analysis of the survey response in the SUBLAND Position Paper, with the tabulated response data attached as an annexe or available electronically on request to all readers of the Paper
Yes (7) (Belgium, Slovenia, Scotland, England, Northern Ireland, both Norwegian participants) the rest have not answered the question

Full publication of the analysis of the survey response in the SUBLAND Position Paper, with the tabulated response data provided confidentially only to members of EAC and the European Marine Board: Yes (2)

Abbreviated summary of the statistics of the survey response in the text of SUBLAND Position Paper, with a fuller discussion in an annexe, and the full tabulated response data provided confidentially only to members of EAC and the European Marine Board.

Conclusion

Although most nations comply with the international conventions on cultural heritage, surprisingly few nations have signed on to UNESCO Convention on Underwater Cultural Heritage which would probably have had an impact on national legal framework. The regulatory, management, protection, and enforcement aspects of submerged prehistory are as a general rule administered by a national entity and embraced by national legislation and measures, on a regional level there seems to be a variety of ways to carry out the responsibility throughout Europe - depending on heritage management organization as such. The degree of privatization of heritage practice also plays a part in how the responsibilities and roles are sorted. We can conclude that most of our respondents carry responsibility within the beach and intertidal zone (11). Germany, Scotland, Norway and Iceland (4) have, however, responded that they are not responsible for management on the beach and in the intertidal zone. For Norway there seems to be a difference in responsibility for Maritime Museums between regions of Norway. Most of our respondents are also responsible for management within the territorial waters (sea) (12). Only a few of our respondents are responsible for archaeology within the extended contiguous zone (4), Norway, The Netherlands, Greece and the Denmark. Due to a complete overlap between the EZZ and the continental shelf in the relevant waters The Netherlands to a limited degree (dredging, oil/gas exploration) has responsibility on the shelf. Scotland has marine licensing powers within the 200 nm zone, a national significant discovery could however only be scheduled within the 12 miles zone.

Prehistoric remains found on the seabed are to a large degree covered or intended to be covered by legal measures among the responding nations. The most common rule is that legal requirements for seabed industrial and commercial operations apply, legislation for protection and conservations is also widespread. Research and interpretation is quite weakly covered by laws. Both filing plans and assessing the probability of disturbing prehistoric remains on the seabed are requirements from the developers that seem to be widespread among the respondents.

The countries around the Irish Sea, North Sea and the Western Baltic as well as the Eastern Mediterranean answer positive to most of the questions that indicate a systematic regulation and include measures with respect to heritage and prehistoric sites. Denmark seems to take complete control by involving their own pre-investigations when operations and intervention are planned on the seabed, while the other nations to some degree collaborate with the developer in order to have qualified personnel on board vessels and monitor the seabed. Scotland and England impose demands on a case-by-case basis or through EIA processes. When it comes to obtaining commercial datasets from developers it seems to be the countries that apply a licensing instrument that have the strongest regulations for obtaining and archiving such data. Concerning Denmark this is obtained through their own investigations. Greece is strongly regulating access to such data towards research while in several countries there is an intention to request data, but it does not happen.

Considering inspection and enforcement there are in the majority of the responding countries legal measures associated with development and obligations to protect submerged prehistoric sites in the managed territorial waters.

The section on collaboration with marine geoscience and survey agencies and institutes, does not report which types of geoscientific collaboration that actually takes place in the responding countries – but it gives a clear indication that respondent see potential in such collaboration across all the mentioned sectors.

Although the questionnaire reports on advances and progress in the field of prehistoric archaeology on the seabed it is also clear that the thematic field is still quite fragmented and from time to time weak regarding the actual possibility for fulfilling the intentions of laws and regulations. The WG concludes that this field is still in need of considerable support and international collaboration in order to consolidate sustainable management and research.

Design: Zoeck nv

Cover image: Diver surveying Pavlopetri Early Bronze Age site (Credit: J. Henderson)

European
MARINE BOARD
Advancing Seas & Oceans Science

Wandelaarkaai 7 I 8400 Ostend I Belgium
Tel.: +32(0)59 34 01 63 I Fax: +32.(0)59 34 01 65
E-mail: info@marineboard.eu
www.marineboard.eu